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ALPHABET

OF

SCIENTIFIC CHEMISTRY.

ALPHABET

OF

SCIENTIFIC CHEMISTRY,

FOR

THE USE OF BEGINNERS.

BY JAMES RENNIE, M.A.,

PROFESSOR OF ZOOLOGY, KING'S-COLLEGE, LONDON; AUTHOR OF "A NEW SUPPLEMENT TO THE PHARMACOPŒIAS," &c.

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PLAN OF THE WORK.

I WELL recollect the first chemical experiment I ever witnessed, which was performed by my distinguished instructor, Dr. Ure, in the Andersonian Institution, Glasgow, and went to prove that water is composed of two different sorts of air, or, as chemists term them, gases. I was delighted—I may rather say enraptured—with the clearness of the unquestionable and irresistible proofs, and lay awake the greater part of the following night, mentally repeating and re-repeating the premises and the inferences therefrom, and wishing (vainly indeed, but I could not help it,) that it had fallen to my lot to have made Cavendish's discovery of the extraordinary facts of the composition of water. My mind was roused into a train of thinking entirely new, and as I pondered over the various circumstances, fresh combinations arose in numerous and delightful succession. I know not, indeed, that I ever experienced greater pleasure afterwards, even when I had mastered the rudiments of the science, and heard from another highly distinguished chemist, Dr. Thomson, whose pupil I also had the good fortune to be, the interesting doctrine of proportional combination, than I first felt from seeing the composition and decomposition of water.

I have mentioned the preceding as an individual instance of the pleasures arising from the study of chemistry, to show that they may all be traced to the general source of awakening the mind to activity, rousing up into life ideas previously dormant, and bringing into play the various processes of investigation, comparison, and decision; a principle which, so far as we can judge, obtains universally, in whatever channel the taste of individuals may run. In a chemical experiment, one portion of the pleasure also arises from comparing the original state of the materials employed, with the results either of separation or of combination which the experiment effects; while in painting and the other imitative arts, the pleasure in part arises from the comparisons and decisions made by the mind, between the imitation of the artist and the thing imitated.

Independently then of its utility in arts and manufactures, it will follow from the general principle just laid down, that the study of chemistry is entitled to rank high as a source of refined intellectual pleasure, endless as the experiments which may be devised, and varied without the possibility of exhaustion. I cannot better exhibit the pleasure and utility combined in this fascinating study, than in the words of Sir John Herschel.

"The wonderful and sudden transformations," he says, "with which chemistry is conversant, the violent activity often assumed by substances usually considered the most inert and sluggish, and, above all, the insight it gives into the nature of innumerable operations which we see daily carried on around us, have contributed to render it the most popular, as it is one of the most extensively useful, of the sciences; and we shall, accordingly, find none which have sprung forward, during the last century, with such extraordinary vigour, and have had such extensive influence in promoting corresponding progress in others. One of the chief causes of its popularity is, perhaps, to be sought for in this, that it is, of all the sciences, perhaps the most completely an experimental one; and even its theories are, for the most part, of that generally intelligible and readily applicable kind which demand no intense concentration of thought, and lead to no profound mathematical researches. The simple process of inductive generalisation, grounded on the examination of numerous facts, all of them presenting considerable intrinsic interest, has sufficed, in most instances, to lead, by a clear and direct road, to its highest laws yet known.

"Every department of art has felt the influence of these, and new instances are continually starting forth of the unlimited resources which this wonderful science developes in the most sterile parts of nature. Not to mention the impulse which its progress has given to a host of other sciences, which will come more particularly under consideration in another part of this discourse, what strange and unexpected results has it not brought to light in its application to some of the most common objects! Who, for instance, would have conceived that linen rags were capable of producing *more than their own weight* of sugar, by the simple agency of one of the cheapest and most abundant acids?—that dry bones could be a magazine of nutriment, capable of preservation for years, and ready to yield up their sustenance in the form best adapted to the support of life, on the application of that powerful agent, steam, which enters so largely into all our processes, or of an acid at once cheap and durable?—that saw-dust itself is susceptible of conversion into a substance bearing no remote analogy to bread; and though certainly less palatable than that of flour, yet no way disagreeable, and both wholesome and digestible as well as highly nutritive? What economy in all processes where chemical agents are employed, is introduced by the exact knowledge of the proportions in which natural elements unite, and their mutual powers of displacing each other! What perfection in all the arts where fire is employed, either in its more violent applications, (as, for instance, in the smelting of metals by the introduction of well adapted fluxes, whereby we obtain the whole produce of the ore in its present state) or in its milder forms, as in sugar-refining, (the whole modern practice of which depends on a curious and delicate mark of a late eminent scientific chemist, on the nice adjustment of the temperature, at which the crystallization of syrup takes place); and a thousand other arts which it would be tedious to enumerate!"

It would require a treatise like those of Chaptal, Parkes, and Dumas to show the extensive utility of chemical knowledge in manufactures, and it is intended as soon as possible to take up the various branches of BLEACHING, DYEING, BREWING, BREADMAKING, and other chemical manufactures, uniform in plan with this ALPHABET, which may be considered as introductory to these and three others, required to complete our original design.

As in the other little works of this series, I have tried every possible means to render the subject plain, and up to the division where the principle upon which chemical terms are formed is explained, I have mentioned none in the text that could by possibility be *avoided*. I have besides introduced, for the sake of interest and variety, as well as of illustration, a greater number of experiments than I at first deemed necessary in accordance with my plan.

It may be well, at the outset, to point out to the beginner, the difference between the study of Chemistry which proceeds by experiment, and the study of Natural History, which proceeds upon observation, (both make use of analogy) ; and I cannot do this better than in the words of Sir H. Davy, decidedly one of the most distinguished chemists who have hitherto appeared.

"The foundations of chemical knowledge," he says, "are, observation, experiment, and analogy. By observation, facts are distinctly and minutely impressed on the mind ; by analogy, similar facts are connected; by experiment, new facts are discovered : and in the progression of knowledge, observation, guided by analogy, leads to experiment ; and analogy, confirmed by experiment, becomes scientific truth. To give an instance,—whoever will consider with attention the slender green vegetable fibres of crow silk (*Conferva*) which, in the summer, exist in almost all streams, lakes, or pools, under the different circumstances of shade and sunshine, will discover globules of air upon the filaments exposed under water to the sun, but no air on those that are shaded. He will find that the effect is owing to the presence of light. This is an *observation ;* but it gives no information respecting the nature of the air.

"Let a wine-glass filled with water be inverted over the crow silk (*Conferva*) ; the air will collect in the upper part of the glass, and when the glass is filled with air, it may be closed by the hand, placed in its usual position, and an inflamed taper introduced into it ; the taper will burn with more brilliancy than *in the atmosphere.* This is an *experiment.*

"If the phenomena are reasoned upon, and the question put, whether all vegetables of this kind, in fresh or in salt water, do not produce such air under like circumstances? the inquirer is guided by *analogy*; and when this is determined to be the case by new trials, a general scientific truth is established, namely, that all plants of crow silk (*Conferva*), in the sunshine produce a species of air that supports flame in a superior degree."

The best works on the subject for the student to peruse, after he has mastered the Alphabet, will appear from the numerous references which I have made throughout, in mentioning the discoveries of individual chemists.

I am indebted to Messrs. Agnew and Zanetti, of Manchester, for the portrait of Mr. Dalton, which forms the vignette to the title-page. It is copied from a print published by those gentlemen, and is a good likeness of the first chemist of this country.

ALPHABET OF SCIENTIFIC CHEMISTRY.

THE WORD CHEMISTRY.

THE older experimenters had a notion that lead, iron, and other metals, could be changed into gold, by means of what was termed the *philosopher's stone*, the discovery of which it was their grand aim to effect; and though it appears evident from the properties of gold that no discovery of this kind could ever be made, yet the numerous experiments tried with this view, led to the investigation of many important facts. Most of such experiments were made by means of fire, and hence, in Arabia, where they were at one time much pursued, the experimenters were termed *Alchemists*, meaning "The Firists," or "The Fire Philosophers;" and metaphorically "The

Enthusiasts;"—and, higher still, "The Celestials,"—the word *Al*, in Arabic, being similar to our word "The."

The Alchemist, Basil Valentine, at his furnace.

The word "Chemistry," then, formed by dropping the Arabic *Al*, and modifying the termination, after the English form of "Ministry" and "Registry," strictly signifies "Fire Science," and though, in general, it means more than this in modern books, we shall see, as we proceed, that the action of fire, or heat, is, or ought to be, one of the chief objects of chemical study.

Taking the word "Chemistry" in its most comprehensive sense, it appears to mean the science of the composition and decomposition of substances. This, *of course*, includes the laws by which substances are composed or decomposed, as well as a knowledge of the simple substances which enter into any compound substance.

If the reader will take the trouble to compare the above with what are very inaccurately termed *definitions* [1] of chemistry, from that of Dr. Black, in 1766, to those of Dr. Turner, and Dr. Ure, he will see that it is plainer to a beginner, and at the same time more comprehensive than any of them.

It appears, then, that chemistry must comprise an extensive portion of the philosophy of nature; but it is usual and convenient to distinguish it from what is commonly termed natural philosophy, or physics. The distinctions which have been made do not apply very accurately in every instance; but it may be said, in general, that, in chemistry, we study changes that take place on a small or minute scale; and in physics, those on a great or extensive scale, more particularly motions and the forces producing them, as well as the weight, density, size, and form of the substances moved. Chemistry, on the other hand, has little to do with such motions as are apparent to the eye, chemical changes being generally effected without any perceptible motion; for such motions as occur in boiling and in effervescence are accounted for by physics.

If a loaf of bread, as Mrs. Marcet remarks, be cut

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(1) The term *definition* is from the Aristotelian Logic, and has been productive of much injury to science, as will be shown in the "ALPHABET OF INDUCTIVE LOGIC."

into slices, or grated down, the operation is physical; if it could be separated into the flour, the yeast, the water, and the salt with which it was made, the process would be chemical.

Again, if I break a piece of chalk with a hammer, the motion of the separated particles is visible, but they undergo no change of composition, each particle being white and brittle, like its fellow, consequently their separation is merely physical. But chalk[1] is a compound, and not a simple substance, and if I separate it into a particular sort of earth[2], and a particular sort of gas[3], of which it is composed, the separation is chemical. This separation could even be carried farther, for the earth itself, thus separated from chalk, is composed of a sort of metal[4], and a sort of gas[5]; and the gas first obtained is composed of pure charcoal[6], and another gas, as we shall afterwards explain at length.

Chemistry, then, is distinct from physics, though the two are often advantageously blended in philosophical investigations; for the knowledge of one great class of facts always bears more or less on the knowledge of other classes of facts, and consequently nothing can be more injurious to a student's progress than confining the attention exclusively to one science. It was by combining his chemical knowledge of heat with his physical knowledge of mechanism,

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(1) Technically, *Carbonate of lime.* (2) Technically, *Lime.*

(3) Technically, *Carbonic acid gas.* (4) Technically, *Calcium.*

(5) Technically, *Oxygen gas.* (6) Technically, *Carbon.*

that Watt perfected the steam engine; and it has been by a similar combination of chemical and physical knowledge, that the various branches of the inestimable art of printing have been so miraculously improved.

ARRANGEMENT OF THE SUBJECT.

In complicated subjects, like that of chemistry, it is often difficult to seize upon a point of view such as shall not confuse a beginner at the out-set, and probably deter him from proceeding. A great number of introductory chemical works commence with explanations of the general laws affecting the composition and decomposition of substances, a method which compels the authors to introduce many things that no mere beginner can possibly understand; for no general position can be understood till the particulars are first mastered, and therefore it is evidently the simpler way to begin with particulars before coming to generals.

As chemistry then is the study of the composition and decomposition of substances, and as composition implies that which is compound, made up of what may be simple, we ought, it would hence appear, to begin with the simples of which compounds are constituted. Modern discovery, however, has rendered simple substances rather numerous, and a mere descriptive catalogue of these, would, by most readers, be considered dry and repulsive; the very worst character that a beginner's book could have.

Taking these circumstances, then, into consideration, I shall follow a sort of middle course; for while I shall avoid the preposterous practice of teaching general laws before the particulars from which these are deduced, I shall equally avoid giving a mere dry catalogue, like the Linnæan books on Natural History, that are useful and indispensable to consult for certain facts, but devoid of the interest requisite to inspire enthusiasm, fascinate the student's attention, and cheer him on as he advances to the higher branches of the science.

With this view, I shall direct the beginner to some of the most common compound substances, such as water and air, and then proceed to the more complicated substances, such as sea-water; an inquiry into the composition of which will lead to several important general principles. It will be previously necessary, however, to give a brief sketch of the kind of substances at present considered simple.

ELEMENTS OF THE ANCIENTS AND THE MODERNS.

It is generally, though I believe erroneously, stated in books, that the ancient philosophers reckoned only four simple substances, out of which all things were compounded. What *they* termed the elements, however, namely, "Fire, Air, Earth, and Water," were certainly not considered in the same light as our chemists now consider simple substances, of which the ancients probably had no more idea than they could have had of the steam engine, or of gas-light.

The things considered simple by modern chemists, are those which have hitherto resisted every means tried to decompose them into things more simple, though it is not at all improbable, that many of them may, in progress of time, be discovered to be compounds, as water was proved to be composed of two gases at the commencement of the greatest era in chemistry, and as potass and lime were more recently proved to be composed of metal and gas.

Endeavours have been made to arrange the things which chemists now consider simple, into classes, but in some instances, very unsuccessfully, so that I shall not at first trouble the beginner with these, but content myself with stating, that there are reckoned forty-one simple metals, six simple solids, not metallic, four simple gases, with the new substance, *bromine*, usually liquid, and a supposed simple substance, named *fluorine*, without taking into account *heat*, and *light*, or the *electric* and *magnetic* principles. In the table at the end of this volume, a complete list is given of simple substances, together with a great number of the principal compounds.

LESSONS ON COMPOUND SUBSTANCES

In pursuance of my plan, I shall now request th beginner's attention to some examples of the substances most universally known in their compound state, but whose composition can only be ascertained by chemistry. In order also to arrest attention, which, on commencing any science, it is no less important than it is difficult to secure, I have introduced the several simple substances with brief historical notices of their discovery, and details of the most striking experiments.

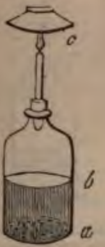
COMPOSITION OF WATER.

I have made choice of water as the subject of our first lesson in chemistry, because it is well known; because the discovery of its composition may be said to have laid the foundation of the science; and because it will bring early into notice some of the principles most important for a beginner to know. A brief history of the discovery may prove more interesting than a mere enumeration of properties.

Discovery of Hydrogen Gas.

The Hon. Mr. Cavendish, in 1766, discovered a peculiar sort of gas which he called inflammable air, from its readily catching fire. This gas is procured *by putting* a handful of iron filings into a bottle and pouring over them some sulphuric acid[1] to which five times its bulk of water has been added, when the gas[2], being very light, will rise out of the bottle, and if set fire to will burn with a dull flame.

Ten years after this discovery, in October, 1776, two French chemists, Macquer and Sigaud de la Fond, being desirous to ascertain whether the flame of Cavendish's gas produced any soot, tried the experiment of holding a white china saucer over the flame; but, instead of soot, the saucer was bedewed with small drops of what appeared to be pure water, and though the experimenters were not certain of the fact, nor aware of its importance, this was probably the first water observed to be formed by experiment.



Macquer's experiment;—*a*, iron filings; *b*, sulphuric acid and water; *c*, the gas flame.

Five years afterwards, in April, 1781, Mr. Warltire, encouraged by Dr. Priestley, fired a mixture of

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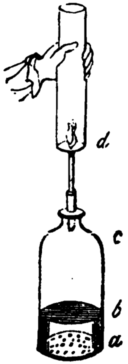
(1) Popularly, *Vitriol* or *Oil of Vitriol;* in Latin, *Acidum Sulphuricum.*

(2) Technically, Hydrogen Gas.

Cavendish's gas and common air in a close copper vessel, when it was found that the weight was diminished; and when Dr. Priestley and Mr. Warltire repeated this in a close dry glass vessel, it was found bedewed with moisture, and also with a sort of soot, in consequence, no doubt, of some inaccuracy; for when this was repeated by Mr. Cavendish and Dr. Priestley, the same result did not follow.



Cavendish's experiment:—*a*, iron filings; *b*, the sulphuric mixed with water; *c*, the gas mixed with air; *d*, the gas fl introduced into the glass tube.

In the summer of the same year, Mr. Cavend being anxious to ascertain what becomes of the that disappears in the process of burning[1], bur 500,000 grain measures of his gas with about two

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(1) Technically, *Combustion*.

a half times the quantity of common air. The burnt air was made to pass through a glass tube eight feet in length, on the inside of which 135 grains of pure water were formed.

It would appear that Dr. Priestley and Mr. Warltire, so far from understanding the real origin of the water, in their experiments, supposed it to be derived from the moisture previously contained in the air and the gas; but Mr. Watt, in a letter to Dr. Priestley, dated 26th April, 1783, inferred that the water produced was a compound of the air and the gas, which he supposed to unite in consequence of their losing heat in burning, an inference very near the truth, and highly creditable to Watt's deep penetration.

Artificial Formation of Water.

Instead of mixing Cavendish's gas with common air, as in the previous experiments, another gas[1], discovered by Dr. Priestley, in 1774, was tried. Mr. Cavendish mixed in a close vessel 37,000 grain measures of his own gas with 19,500 grain measures of Dr. Priestley's gas, and fired them, when he obtained a portion of water, though not quite pure. This, with his previous experiments, was communicated to the Royal Society on the 15th January, 1784, but Dr. Blagden informed Lavoisier on the 24th June, 1783, that Mr. Cavendish had performed the preceding experiment and procured water, so that his title to this important discovery is unquestionable.

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(2) Technically, Oxygen gas.

In the summer of 1783, some of the most distinguished French chemists resolved to try similar experiments, and on the 24th June, M. Lavoisier, with M. La Place, in presence of Dr. Blagden, secretary of the Royal Society of London, mixed together in a glass vessel over mercury a portion of Cavendish's gas, and a portion of Priestley's gas in greater quantity than had been employed by the English experimenter, and upon burning the mixed gases, they obtained five French *gros* or about 295 English grains of pure water. About or before the same time, M. Monge performed a similar experiment at Paris.

M. Lavoisier, having thus satisfied himself that water was a compound substance made up of the two gases employed in the experiment, contrived, along with M. Meusnier, a method of decomposing water by separating the two constituent gases. With this view he caused steam from boiling water to pass through a red-hot iron tube, when he found that the steam disappeared, as well as one of its constituents, the gas of Priestley, while the other constituent, the gas of Cavendish, passed through the iron tube. The following figure will show more plainly how this experiment was or may be performed; but here it may be proper to tell the beginner, that this and some other apparatus, are figured more by way of convenient explanation, than as indispensable for him to procure in performing experiments himself.

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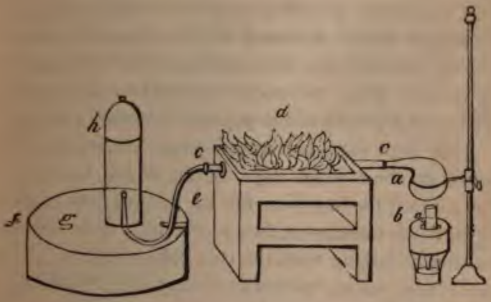
(1) A selection of easy experiments will be given in our "ALPHABET OF AMUSING CHEMISTRY."



Lavoisier's Experiment:—*a*, a glass or porcelain vessel termed a retort, containing water; *b*, a lamp to cause the water to boil; *c*, *c*, an iron tube passing through the furnace *d*; *e*, a bent tin tube passing into the water of the trough *f*, and rising through a hole in the wooden shelf, *g*, over which is placed a glass vessel, called a receiver, *h*, containing water.

When the steam from the water boiled in the retort passes through the iron tube made red-hot in the furnace, it is decomposed, Priestley's gas uniting with the red-hot iron of the tube, and disappearing, while Cavendish's gas passes on into the bent tin tube, and may be seen rising in bubbles through the water of the receiver. It facilitates the process to fill the iron tube with a coil of fine iron wire, or with charcoal.

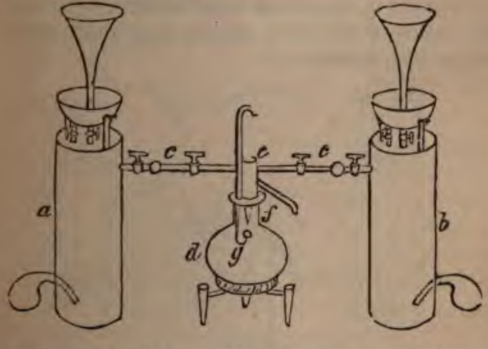
Seven years afterwards, the French chemists, Fourcroy, Vauquelin, and Seguin, began on Wednesday, the 13th of May, 1790, their celebrated experiment, to prove, beyond any future question, the composition of water, by employing a much greater quantity of materials than had been done in previous experiments. Of Cavendish's gas, they employed 1030·358 grains by weight, which measured 25963·568 solid inches; and of Priestley's gas they employed 6209·869 grains by weight, which measured 12570·942 solid inches. The united weight of the gas was 7249·227 grains.

They kept these two mixed gases burning for 185 hours, or about eight days, during which time they did not quit the machine for an instant, but resting by turns on mattrasses, they successively relieved one another as fatigue rendered this indispensable. The experiment was completed on Friday, the 22d of May, when the water obtained weighed 7244 grains, or more than a pint, the loss in the original weight of the gases being consequently 4·227 grains. It was on examination found to possess all the qualities of distilled water.

These experiments, performed with so much enthusiastic perseverance, triumphantly proved that water is a compound substance, as it can both be separated into two gases, and these gases can again be combined into water; two processes which cannot, from the imperfection of our contrivances, be always successfully performed with regard to other substances subjected to chemical experiment. The experiments, however, of the distinguished discoverers of the composition of water, are not the most practicable or elegant in the present state of the science.

It will be convenient before proceeding, to state, that M. Lavoisier gave to Cavendish's gas the name of *hydrogen*[1] gas, and to Priestley's gas the name of *oxygen*[2] gas, which terms we shall hereafter use.

Subsequently to his first experiments, M. Lavoisier contrived a very ingenious method of proving very exactly the composition of water, which was afterwards improved by Cuthbertson and others, according to the following figure :—



Experiment for the composition of water :—*a*, a gas-holder, containing hydrogen gas ; *b*, a gas-holder containing oxygen gas ; *c*, *c*, tubes with stop-cocks, along which the two gases may pass into the glass globe *d*, through the stopper *e*, which has two holes to admit them, and a brass wire *f*, as well as the bent wire with a platinum knob, *g*.

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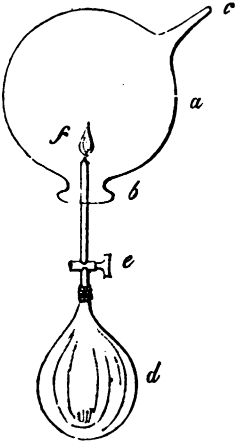
(1) From the Greek *ὕδωρ*, " water," and *γενναω*, " I generate," meaning, therefore, " water-generator."

(2) From the Greek *οξυς*, " acid," and *γενναω*, " I generate," meaning " acid-generator."

When this arrangement has been made, a succession of sparks from the prime conductor of an electrical machine are passed between the platinum knob and the brass wire, while first the hydrogen gas is admitted and kindled, and then the oxygen gas. It is requisite to keep the glass globe cool by means of wet cloths, when the water generated will collect on its sides and bottom.

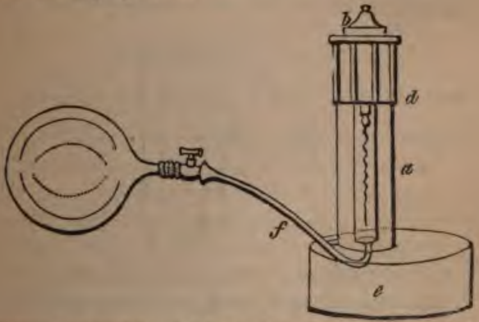
Those who have no better apparatus, may satisfy themselves of the general result of these experiments by means of one more simple, as in the following figure from Henry :—



Henry's experiment for the composition of water :—*a*, a glass globe capable of holding three or four quarts of water, *having* one wide opening *b*, and one narrow *c*; *d*, a bladder *taining* hydrogen gas fitted with a tube and stop-cock e

Unscrew the stopcock, and set fire to the hydrogen gas that escapes out, and introduce it into the glass globe, and let it continue to burn till water is seen to form in drops on the inside of the glass.

The most elegant mode of showing the composition of water, is the exploding of one measure of oxygen gas mixed with two measures of hydrogen gas in an instrument termed a *Eudiometer*[1], by means of an electric spark from a charged Leyden jar. The instrument, invented by Volta, will be best understood from the following figure :—



Volta's Eudiometer :—*a*, a tube of very thick and strong glass, open at bottom and closed at the top *b*, by a brass stopper, with a knob *c*. In the interior is placed a spiral copper wire ending in a knot at *d*. The tube is filled with water, and placed on a shelf with a hole in it in the trough *e*, and there is then passed up into the glass by means of a bent tube, *f*, two measures of hydrogen gas and one measure of oxygen gas.

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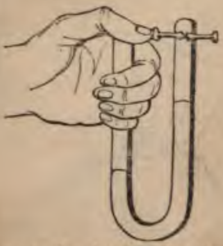
(1) From the Greek *ευ*, "pure," *δια*, "air," and *μετρον*, "measure," meaning therefore "Pure-air-measurer."

Electric sparks are then passed in succession through the brass knob *c*, when the gases are kindled, and if the experiment has been accurately performed, not a particle of any of the gases will remain, the whole having combined to form water.

Dr. Ure has invented a more convenient instrument of this kind, in which the glass tube is bent so as to render it easy for the experimenter to touch one of the brass knobs with his thumb, which carries off the electricity received from a jar, or a conductor on the opposite side, as may be seen in the following figure :—



Dr. Ure's Eudiometer for showing the composition of water.

The composition of water just given, applies only to pure water, which is rarely to be procured, except by artificial means. Rain water is tolerably pure, but usually contains some compound of lime ; while the waters of rivers, springs, and pumps, but more particularly what are termed mineral or medicinal waters, contain varying proportions of salts, gases, and earthy or metallic compounds, which would only tend to puzzle a beginner, were I to introduce them here. I at first intended, however, to examine in this place the composition of sea-water, for the purpose of making the reader acquainted with some very interesting and recently discovered substances which it contains ; but, on further consideration, I have judged it better previously to take up the much more simple composition of air, it being always an important object with me not to hurry the student into the midst of things which he may not find it so easy to comprehend. The composition of common water will again come under prominent notice when treating of heat.

COMPOSITION OF THE AIR OF THE ATMOSPHERE.

The air around us has, when pure, no perceptible taste nor smell, and in small quantities has no colour ; but in large quantities, when full of watery vapours, it becomes grey or white, and when it contains little moisture, it becomes beautifully blue, as is seen in a cloudless sky. That it is only a considerable extent of air that becomes blue, appears from the blue tint of the sky appearing paler and brighter at the level of of the sea than on the top of a lofty mountain. Brydone observed, that the sky appeared nearly black on the summit of Mount Ætna ; and I remarked a similar deepness of tint on the summit of the Col de Balme in Savoy. Campbell accordingly is scientifically correct (a rare thing in poetry,) when he says,

> "'Tis *distance* lends enchantment to the view,
> And robes the mountain in its azure hue."
>
> PLEASURES OF HOPE.

That the air has considerable weight, is known to every body who has felt the wind blow, or seen a ship sail; and it was discovered in 1640, by Galileo, and afterwards proved by Torricelli and Pascal, that at or near the level of the level of the sea, it presses with a weight of about fifteen pounds upon every square inch; consequently, upon the square inch in the following figure, the air at this moment presses with a weight of fifteen pounds.

Square inch to illustrate the weight of the air.

Consequently a man of ordinary stature will be loaded with air to the amount of about fourteen tons. All this, however, belongs to a branch of physics[1]; but it was judged useful to mention the circumstances briefly before coming to what is strictly chemical.

As in the instance of water, I shall go back to the period of some of the most important discoveries

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(1) The subject will be detailed in the "ALPHABET OF PNEUMATICS."

respecting air. Stahl, a celebrated German chemist, who died about a hundred years ago, was a true *Firist*, explaining most chemical changes by reference to a sort of imaginary principle of fire [1], that led in most cases to erroneous conclusions. When a piece of iron, for example, was burnt till it lost its metallic appearance, and became what I may term a metallic cinder [2], Stahl said, this was in consequence of losing the matter of fire which the metal previously contained, and which escaped in the process of burning. The metallic cinder was accordingly considered simple, while the metal was said to be a compound of this and the matter of fire. Upon this view, however, no explanation could be given of the remarkable circumstance of the alleged simple substance weighing heavier than the alleged compound.

Discovery of Oxygen Gas.

While these opinions of Stahl were in vogue, Dr. Priestley, in 1774, and soon after the celebrated Swedish chemist, Scheele, in 1775, made the important discovery of oxygen gas, which I have above shown to be one of the constituents of water. Dr. Priestley first obtained this gas from the metallic cinder in form of red scales [3], produced by exposing

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(1) Technically, *Phlogiston.*

(2) Technically, *Calx*, in old writers; now *Oxide.*

(3) Technically, *Precipitate per se*, in old writers; now *Peroxide of mercury*; in Latin, *Hydrargyri oxydum.*

quicksilver[1] to a heat of six hundred degrees, and which he exposed in the focus of a burning glass. In 1775, M. Lavoisier, who had begun to suspect the true state of the case, exposed the same substance to heat in the sort of vessel termed a retort, (see page 13) and succeeded in expelling from it a portion of oxygen gas; consequently, before the expulsion of the oxygen gas, it was a compound of this gas and quicksilver, and not a simple substance, as Stahl had conjectured.

Having thus obtained a glimpse of these important views, M. Lavoisier proceeded to put their correctness to the severest tests he could devise, by other experiments. There is a substance procured from animal bones, called *Phosphorus*, simple, so far as is hitherto known, which has somewhat the look of wax, yellowish, translucent, and rather softish, and so inlammable as to catch fire when exposed to the air. t is on this account much used for popular experients, and it is well known to country lads, who by utting some of it on their hands and face, make em appear to be on fire. I may state, however, at it is dangerous for the inexperienced to play cks with, and I myself was once severely burnt by it from want of care. M. Lavoisier put a bit of this substance into a jar containing oxygen gas, and upon burning it there, he found that a considerable quantity of the gas disappeared, while the phosphorus gained weight exactly corresponding to what the gas lost. The following experiment, which is still frequently performed by lecturers, was also contrived by M. Lavoisier.

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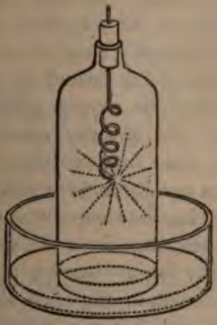
[1] Technically, *Mercury*; in Latin, *Hydrargyrum*.



M. Lavoisier's experiment of burning iron wire in oxygen gas.

A bit of fine iron wire, such as is used for musical strings, is twisted into a spiral; a bit of cork or of charcoal is fixed to the lower end, while the other is fitted into the air-tight stopper of a glass receiver containing oxygen gas, and placed over water to prevent its escape. The bit of cork is set on fire before it is put into the glass, where it causes the wire to burn with a very brilliant light. M. Lavoisier found, as in the former case, that oxygen gas disappeared, while the iron cinder[1] acquired weight equal to the lost gas.

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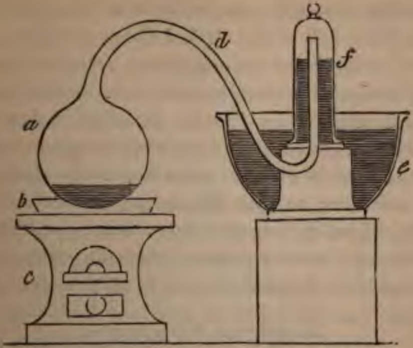
(1) Technically, *Protoxide of iron*; in Latin, *Ferri oxydum nigrum*.

M. Lavoisier tried a still more decisive experiment, by confining a quantity of liquid quicksilver in a vessel containing oxygen gas, and exposing it to heat till the gas disappeared. He then put the substance thus produced (which he very fairly presumed to be composed of the quicksilver and the gas) into a small retort, and on this being heated to redness, he succeeded in expelling the oxygen gas that had disappeared; finding the quantity exactly correspond, while he at the same time procured the fluid quicksilver. This was equally decisive with the celebrated experiments proving the composition of water.

The general inference from the experiments was highly important; for, by burning phosphorus, iron, and other substances, in the open air, a similar increase of weight, and change of external appearance, was produced as when burnt in oxygen gas, there could be no doubt that oxygen gas was, during the burning, taken from the surrounding air, and, consequently, that the common air contains oxygen gas. M. Lavoisier, elated, as he well might be, by the preceding great discoveries, proceeded to try the accuracy of the latter inference by another ingenious experiment; for by performing the counterpart of the experiment, and expelling the oxygen gas, the proof was complete of its having passed, in the experiment of burning, from the air into the phosphorus or the iron.



M. Lavoisier's experiment on the composition of air: *a*, a vessel termed a mattrass of the capacity of fifty cubic inches, placed on the sand pot *b*, and containing dry sand of the distilling furnace *c*, the tube *d* of the mattrass is bent so as to pass through a vessel *e*, containing fluid quicksilver, over which is placed a glass receiver *f*, containing in its upper part an accurately measured quantity of common air, but not more than will fill one third of it.

M. Lavoisier put into the mattrass about 1500 grains of quicksilver, and lighted the furnace fire, which he kept burning for several days, so as to maintain the quicksilver nearly at the boiling point, and freely exposed to the common air, both in the mattrass and in the glass receiver. The first effect produced, was the expansion of the air by the heat, and hence the necessity of enclosing only a small quantity in the receiver, which might otherwise have burst; but after the fire had been kept up for two or three days the air began to disappear, or, at least, to diminish in bulk; and, at the end of the fifth day, when the vessels had cooled, he found that about one sixth of the bulk of the air had disappeared.

On the surface of the quicksilver he found floating small scales, of a puce brown colour, and supposing these to contain the lost air, he collected them, put them into a coated glass tube, subjected them to heat approaching to redness, when a quantity of oxygen gas, answering to that which had disappeared, was expelled from the brown scales. Consequently there could be no doubt remaining, that the common air contains at least one sixth part of oxygen gas.

Discovery of Nitrogen Gas.

The remaining five-sixths of the air, which did not disappear, was found to be very different from oxygen gas, particularly in its remarkable effect of extinguishing flame, while oxygen gas, on the contrary, increases its brightness. This experiment was performed in 1775, and the Swedish chemist, Scheele, made a similar discovery about the same time; but three years previous, in 1772, Dr. Rutherford, of Edinburgh, appears to have observed some of the peculiarites of this gas. M. Lavoisier gave it the name of *Azotic* (1) gas, because it kills animals that breathe it without a mixture of oxygen gas; but it is now more usual to term it *Nitrogen* (2) gas, because it constitutes the basis of nitre, the well known substance popularly termed saltpetre.

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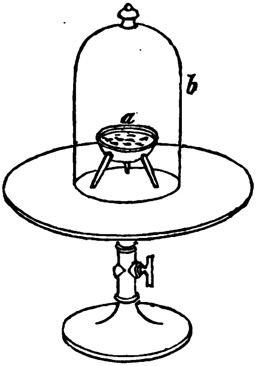
(1) From the Greek, α, "against," and ζωη, "life," meaning "against-life," that is, poisonous.

(2) From the Greek, νιτρον, "nitre," and γενναω, "I generate," meaning "nitre-generator."

The air was accordingly, in this manner, proved to be composed of at least two very different gases, oxygen and nitrogen, as the same experiments repeated will show; but, as it is important to make the beginner clearly understand this, I shall give one or two more experiments in illustration.

Mix in a saucer equal parts of iron filings and sulphur into a paste with water, place it on a stand in a water trough, and over it a glass receiver full of common air. Let this stand for a day or two, when the oxygen of the included air will gradually enter into the



Experiment for decomposing common air. *a*, the saucer with the paste of iron filings and sulphur; *b*, the glass receiver.

paste, and leave the nitrogen gas in the receiver; and if a lighted taper be put into the glass, the nitrogen gas will quickly extinguish it, and it will as quickly kill a mouse or any small animal that may be introduced.

The readiest mode, however, of proving the composition of the air, is by Lavoisier's original experiment of burning a bit of phosphorus in a glass receiver inverted over water, when the phosphorus combines with the oxygen, the compound appearing at first in the form of a white cloud, which afterwards falls down, leaving the nitrogen gas in the glass.

The exact proportions of the two gases contained in common air are from 20 to 21 parts by bulk of oxygen gas, and consequently 80 or 79 parts by bulk of nitrogen gas; a proportion which has been ascertained to be nearly the same in all places of the world and at all heights; air having been examined with this view, from the summit of Mont Blanc, by Saussure; from Spain, by De Marti; from France and Egypt by Berthollet; from England and the Coast of Guinea by Sir H. Davy; from Scotland by Dr. Thomson; from the Peak of Teneriffe; and from near the summit of the Andes by Baron Humboldt; and even from a height of 21,735 feet above the earth as procured in a balloon by Gay Lussac and Thenard. The most surprising result, however, of such experiments, is, that air taken over stagnant water and marshes, and even from the wards of a fever or cholera hospital, gives, according to Seguin and other able chemists, no difference in these proportions, though it may contain more, as we shall presently see, of another gas, different either from oxygen or nitrogen.

Although I have here spoken of the composition of the common air, it may be well to state, that men of science are not quite agreed, whether that composition is chemical or whether it is merely a physical mixture, such as chalk and water. It is not of much importance to a beginner which view be adopted, and he could not well understand the arguments for the two opinions, even if I were to give them.

Discovery of Carbonic Acid Gas.

Amongst other substances which M. Lavoisier burnt in oxygen gas, he tried a piece of charcoal, the result of which was important; for as the charcoal burned away the oxygen gas disappeared, and there remained in its stead another gas peculiar in its properties, since termed *Carbonic*[1] *acid gas.* It had previously been observed, by Dr. Black, in 1775, who called it fixed air, but had long been vaguely known by miners and others under the name of *Choke damp*[2], from its fatal effects when accidentally breathed.

This gas is always found in common air, though in quantities so small, that it was not, as we have seen, taken into account in the earlier experiments on the composition of the air. Its existence in the air is most readily proved by filling any shallow vessel, such as a China saucer, with lime water, and allowing

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(1) From the Latin *Carbo*, a "coal," technically *Carbon*.

(2) *Dampf* is German for "steam," or "vapour."

it to stand uncovered, when the lime in the water, and the carbonic acid gas in the air, will unite and form a thin hard pellicle, or scum, on the surface of the water. If this be removed, as it is formed, the whole of the lime in the water may be thus, in time, combined with the carbonic acid gas, and removed.

That the pellicle is owing to the carbonic acid gas uniting with the lime, may be proved by putting the several pellicles collected into a retort, and subjecting it to heat, when the gas will be driven off, and the lime will be left in the same state as it was when at first dissolved in the water. The pellicles, in fact, have the same chemical composition as chalk, marble, and limestone, all of which are composed of lime and carbonic acid gas.

In M. Lavoisier's experiment of burning charcoal in oxygen gas, it may be remembered, that this gas disappeared, and carbonic acid gas was found in the receiver. It will naturally be asked by a beginner, what became of the oxygen gas? It was not destroyed by the burning, for nothing, so far as we know, can be destroyed, meaning by this term, annihilated; but as the resulting carbonic acid gas was quite colourless, and transparent, it might appear incredible, that it was nothing more than charcoal minutely united with the oxygen gas; yet this was really the case; and as chemistry does not deal in conjectures, the fact was subsequently proved by decomposing it, and procuring the charcoal in the form of very fine powder.

This proof was first made in 1791, by Mr. Smithson Tenant, and afterwards by Dr. Pearson. It may be tried by means of a very thin glass tube, eighteen or twenty inches long, and about a third of an inch wide, sealed at one end, and coated with a mixture of sand and clay, termed a *lute*, within about an inch of the sealed end. When the lute is dry, fill the uncoated part with pure phosphorus, in small pieces, and cover this with very dry chalk. The part of the tube containing the chalk, is then to be made red hot in a portable furnace, and, the moment this is effected, apply to the part, containing the phosphorus, sufficient heat to raise it into vapour. This vapour, from the phosphorus passing over the red hot chalk, will unite with the oxygen in the carbonic acid gas expelled from the chalk, and the charcoal will fall down in the form of a light black powder; while the lime derived from the chalk will afterwards unite with the phosphorus, now combined with the oxygen. The beginner may be recommended to go over this process several times, till he thoroughly comprehends it.

By glancing back over what has already been said of the composition of the air, it will be seen, that it contains twenty, or twenty-one, parts of oxygen gas; eighty, or seventy-nine, parts of nitrogen gas; and I have now to state, that the carbonic acid gas forms about one thousandth part, or rather less.

One remarkable circumstance, with respect to these three gases, is their very different weights, compared with that of common air. If a given bulk of common air, for instance, weigh one ounce, the same bulk of nitrogen gas will weigh about $\frac{97}{100}$ths of an ounce; the same bulk of oxygen gas will weigh one ounce and $\frac{11}{100}$ths; and the same bulk of carbonic acid gas will weigh rather more than an ounce and a half. Now the inference would be, that as carbonic acid gas is so much the heaviest, it would always remain at the surface of the earth, and never rise into the air, while nitrogen gas being so much the lightest, might be supposed always to rise to the summit of the atmosphere. This, however, is not the case; for the air on the top of Mont Blanc was found by Saussure to contain about the usual portion of carbonic acid gas. But it is so far true, that in particular places, such as mines and the upper parts of brewers' vats, where much carbonic acid gas is evolved, it is a considerable time before it rises into the surrounding air; and it is a pretty experiment, in such cases, to let down into it a lighted candle or taper, which will be immediately extinguished, while the smoke will spread over the surface of the gas, and may be tossed about like waves of water.

Constituents of Sea Air.

Several of the effects of sea air have attracted
attention of philosophers to the producing ca
such as its greater power in bleaching linen, a
causing artificial colours to fade, or change; but

particularly its remarkable action upon plants and animals. I have already stated, that the proportion of nitrogen, oxygen, and carbonic acid gas, is nearly the same in the air of all parts of the world, including sea air; but as there can be no doubt of the important effects of the carbonic acid gas, though it compose less than one thousandth part of the atmosphere, we may infer, that even smaller portions of substances, if they have very active properties, may produce considerable effects. Experiment proves that such is the fact with respect to sea air.

Its bleaching properties evidently depend upon minute portions of the sea water derived from the spray, and carried about by the winds, and as this contains a considerable portion of the principal substance [1] used in artificial bleaching, the cause of the effect becomes evident. The effect of the sea air on plants is no less remarkable. Some will not thrive by any care in the neighbourhood of the sea, and others will not thrive at a distance from it. During the late war between France and Spain, the French manufacturers, being greatly distressed for soda, which they had previously imported from Spain, endeavoured to cultivate kelpwort [2], in the South of France; when they found that if it were planted on the south side of a hill, sloping towards the sea, the crop succeeded well, but when planted on the north

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(1) Technically, *Chlorine*. See the "Composition of Sea Water" for details.

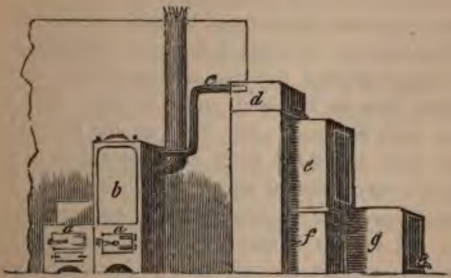
(2) Botanically, *Salsola Kali*.

side of the same hill, where it was screened from the sea breezes, it failed completely; for though the plants grew to the same size, they contained no soda. The well ascertained effect, also, of sea air upon invalids—injuring some and benefiting others,—must be ascribed to the same causes.

COMPOSITION OF SEA-WATER.

Most of my readers must be acquainted with sea-water, and will readily suppose, from its salt and nauseous taste, that it differs much in composition from fresh water. It, in fact, contains, along with the constituents of common water, several other substances very important in chemistry, though from this composition being more complicated than common water, it will not perhaps be quite so easy to make it plain to a beginner.

In consequence of the considerable quantity of common water contained in sea-water, various proposals have been made to procure this, by separating the salt from it on board of ships. This may be managed on the principle of distillation, by boiling the sea-water and condensing the steam, for which purpose the following apparatus has been recommended in that very useful publication, "The Mechanic's Magazine."



Apparatus for rendering salt water fresh :—*a*, *a*, Frasers patent stove; *b*, copper for the sea-water. *c*, a steam pipe which runs into *d*, a trough containing cold water to condense the steam; *e*, *f*, a filtering well for the fresh water to pass through sand into *g*, the reservoir.

So much then for the common water, contained in sea-water. I shall next notice the salt which it contains. When a bit of cloth that has been dipped in sea-water is dried, a white powdery substance remains on the surface, which tastes salt like the original water. This is common salt; and to obtain it in quantity, it is only necessary to dry (if I may thus use the term) a great quantity of sea-water, which is done by exposing it to heat sufficient to drive off, in vapour, all the common, or fresh, water in which the salt is originally dissolved. In order then to know more exactly the composition of sea-water, it will be necessary to examine this salt, in order to discover whether it be simple or compound.

Constituents of Common Salt.

Any one who has observed the difference between the fine table salt common in England, compared with the course grained bitterish salt, presented at the country inns in Scotland, and still more with the black stuff, like coal ashes, usual on the Continent, must infer that these three sorts contain, as in fact they do, very different chemical constituents. But it will answer our present purpose best, to examine such salt only as is quite pure; and we shall find that it is a compound of two very interesting substances, for the accurate knowledge of which we are indebted to Sir H. Davy; since M. Lavoisier and the French chemists, with all their penetration and enthusiastic perseverance, completely failed in this instance, and fell first into one error, and then into others, in their endeavours to extricate themselves. The subject, it will thence appear, is not by any means an easy one.

Discovery of Chlorine.

In order to procure from common salt what I may call its most active constituent, we must use a substance called in the shops black manganese (1), which consists of three and a half parts of the metal of manganese, united with two parts of oxygen. Mix in a mortar one part of this black manganese, finely powdered, with three parts of common salt, and put them into a glass retort, adding two parts of sulphuric acid [2], diluted with an equal weight of water, when a brisk action, termed effervescence, will ensue, and a gas will be expelled from the paste; but more gas will be expelled by means of a gentle heat, taking care not to increase it so as to cause the paste to boil up into the neck of the retort. This gas may be collected over warm, not cold, water, in the manner I have already shown, with respect to oxygen and hydrogen gas.

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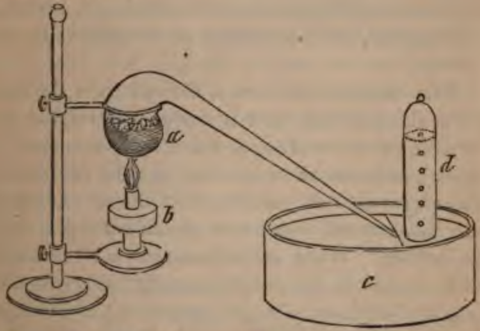
(1) Technically, *Peroxide of manganese.*



Experiment on the decomposition of common salt:—*a*, the glass retort containing the paste; *b*, a lamp for heating it; *c*, the water trough, with *d*, a glass receiver, through the water in which the gas may be seen to rise.

This gas was erroneously supposed by M. Lavoisier to be composed of oxygen and another gas, but Sir

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(1) Popularly, *Oil of vitriol*.

H. Davy, after subjecting it to the severest tests he could devise, pronounced it to be simple, and very similar to many of its properties to oxygen. He named it *Chlorine*[1] gas on account of its greenish yellow colour, which, however, can only be distinguished in day light, for by candle light it appears as colourless and transparent as oxygen gas; but it may always be recognised by its very peculiar suffocating smell, though it is dangerous to breathe it when strong. It may be farther mentioned, that the flame of a taper, when introduced into it, becomes first pale, then red, and, by consuming the gas, soon becomes extinguished, on a principle to be afterwards explained.

This chlorine gas then is derived from the salt; for as the sulphuric acid is made up of sulphur and oxygen, the water of oxygen and hydrogen, and the black manganese of oxygen and metallic manganese, there were no other ingredients in the retort besides the common salt from which the chlorine gas could be derived. When the chlorine gas is all removed, there remain in the retort two substances, one composed of sulphuric acid and manganese[2], and another composed of sulphuric acid and soda[3], the latter well known under the popular name of Glauber's salts, which had simply the name of *salts*, before the

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(1) From the Greek, *χλωρος*, 'green." M. Lavoisier's name for it was, *Oxymuriatic Acid Gas.*

(2) Technically, *Sulphate of Manganese.*

(3) Technically, *Sulphate of Soda.*

milder medicine, Epsom salts, superseded it in popularity.

It may consequently be inferred, then, from the preceding statement, that this soda was included in the common salt in the retort as well as the chlorine gas; and though it does not exactly prove that common salt is a compound of chlorine and soda, it renders this very probable.

We have seen that chlorine gas, having never been decomposed, is now considered to be simple; but this is not the case with soda, which we shall next examine. It would be the most regular way here, to take the compound produced in the retort of sulphuric acid and soda, and procure the soda pure by expelling the sulphuric acid; but as that would lead me too far from my present purpose of showing the composition of sea-water, I must make use of some pure soda (1) already made by a peculiar process, not, however, what is termed soda (2) by the grocer and the laundress, which is a different substance.

Discovery of Sodium.

In 1807, Sir H. Davy discovered that what is termed pure or caustic soda has a metallic base, by means of the powerful instrument called the Voltaic battery, from its celebrated inventor Volta, as represented in the following figure, improved by Cruikshank.

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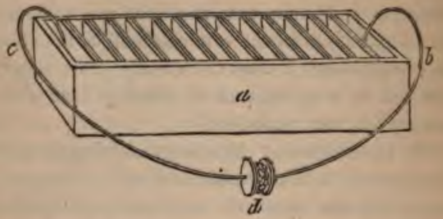
(1) Technically, *Hydrate of Soda*, or *Caustic Soda*.

(2) Technically, *Carbonate of* Soda.



Sir H. Davy's experiment on soda: *a*, the Voltaic battery; *b*, the positive wire; *c*, the negative wire; *d*, the soda.

Moisten with the breath a piece of pure or caustic soda, place it between two discs of the metal called platinum, and bring these into contact with the two wires of the Voltaic battery, which must, for perfect success, be made with two hundred double plates, each four inches square[1]. The soda, in this case, will soon melt, and small globules of metal, similar to silver, though rather soft, will collect at the negative side, while oxygen will go to the positive. Soda, then, consists of chlorine and this metal, which Sir H. Davy very properly termed *Sodium;* and we might then conclude that common salt is composed of chlo-

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(1) This will be more fully detailed in the "ALPHABET OF GALVANISM."

rine and soda, and so it is while it remains dissolved in sea water; but Sir H. Davy proved, that the dry salt contained no soda, that is, no compound of oxygen with the metallic sodium, being solely composed of sodium and chlorine, without any oxygen or other substance. This he proved beyond all question, by burning sodium in chlorine gas, when the result was pure common salt[1].

Constituents of Hydrochloric Acid.

I have said that this composition of chlorine and sodium, only exists in the dry state, but as we are now enquiring into the composition of sea water, it will be important to examine, likewise, in what state the salt exists there, and for this purpose it will be necessary to recollect, that one of the principal ingredients forming common water is hydrogen gas. When a portion, then, of dry common salt, composed, as we have seen, of chlorine and sodium, is put into pure water, it dissolves, and a portion of the oxygen in the water unites with the sodium forming soda, while the chlorine unites with a portion of the hydrogen in the water, forming an acid, hence termed *Hydrochloric acid*[2], which acid unites with the newly formed soda, and remains in solution. This last

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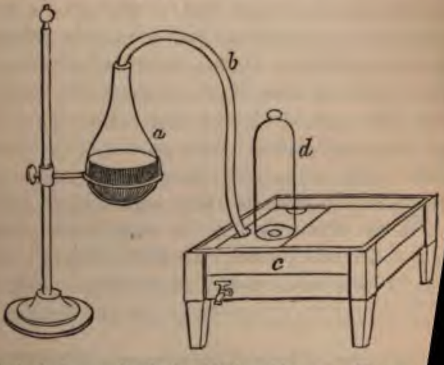
(1) Technically, *Chloride of Sodium*, formerly, and erroneously, *Muriate of Soda*, as it contains no soda nor muriatic acid.

(2) Formerly, *Muriatic Acid*, in old works, *Marine Acid*; popularly *Spirit of Salt*.

compound, then, is that which gives the salt taste to sea water.

It may be proper to mention here, that the hydrochloric acid just mentioned, may be formed in the state of gas, which was first observed by Dr. Priestley, in 1772, by pouring strong sulphuric acid on an equal weight of common salt, when brisk effervescence will ensue, and white fumes will immediately arise, of a penetrating and suffocative odour. This is the hydrochloric acid gas, mixed with a little moisture of the atmosphere. If the mixture be put into a Florence flask, over a lamp, with a bent tube adapted to it, and the gas collected over quicksilver, it may be obtained pure.



Method of procuring hydrochloric acid gas:—*a*, Florence containing equal weights of common salt and sulphuric *b*, bent tube; *c*, trough containing quicksilver; *d*, glass re for the gas.

The truth of the preceding statement, respecting the composition of hydrochloric acid, is proved by placing in a glass receiver equal measures of chlorine gas and hydrogen gas, and exposing them to an electric discharge; to heat; or for some time to light, when they will unite and form exactly two measures of hydrochloric acid. This gas differs, remarkably, from chlorine gas in extinguishing flame, and from hydrogen gas, in not being inflammable.

Discovery of Magnesium and Calcium.

Besides these compound substances, found in sea-water, there is one which has long been known, which it may be important to notice in detail. I refer to what is well known under the name of *Calcined magnesia* [1], but was confounded with lime till it was distinguished by Hoffman, about a hundred years ago.

In what I have above termed the drying of sea-water when done on the large scale in the salt works, there always remains a quantity of water that refuses to dry with the usual heat, which is termed the *Mother water* or *Bittern*. This is composed chiefly of the hydrochloric acid united with magnesia [2], and also sulphuric acid united with magnesia [3]; which magnesia is obtained pure by removing those acids

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(1) Technically, *Oxide of Magnesium.*

(2) Technically, *Hydrochlorate of Magnesia,* formerly *Muriate of Magnesia.*

(3) Technically, *Sulphate of Magnesia,* popularly, *Epsom Salts.*

according to a particular method, which it would be inconvenient to detail in this place.

It is important to mention, that this magnesia, like soda, as formerly mentioned, is composed, as was discovered by Sir H. Davy, of a metal termed *Magnesium*, combined with oxygen, and M. Bussy says the metal is of a lead colour, but little is yet known of it.

There is also in sea-water, as in most fresh water, a small quantity of lime, which like magnesia, is composed of a metal termed *Calcium*, united with oxygen, combined with one or more of the acids; but this is not in quantity sufficient to render it important for our present purpose, though it is probable that it furnishes the chief materials whence the bones of fish and the shells of sea-slugs[1] and corals are formed. The acids combined with the lime are the hydrochloric and the sulphuric, the latter of which is composed of sulphur and oxygen.

Such was the state of chemical knowledge relative to the composition of sea-water, up till about twenty years ago; since then two other important substances have been discovered in it, whose very existence in nature was not previously known. These it will be useful to examine briefly; and here I may remark that it was a happy thought of the old chemist, Glauber, to submit to chemical examination the things which others threw away, as it was the acting upon this notion that led to the discoveries in question.

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(1) In Latin, *Mollusca*.

Discovery of Iodine.

One of the substances to which I have just alluded, and which is termed *Hydriodic acid*, has not been proved to exist in all sea water, but as it has been detected in the Mediterranean Sea, and in the similar water of the salt springs in England, while it is also found in shell-fish and abundantly in most sea-weeds, it is probable that it is more universally diffused than has yet been ascertained. The hydriodic acid, which may be procured both in the state of a gas and of a liquid, is a compound of hydrogen gas and a peculiar substance, which, having hitherto resisted every means taken to decompose it, is reckoned simple.

In 1812, M. De Courtois, a manufacturing chemist at Paris, observed, that in preparing soda from sea-weeds, his metal vessels were much corroded, and on putting into the corroding liquid some sulphuric acid, he obtained a dark-coloured substance, which, on being subjected to heat, rose in vapour of a beautiful violet colour. This was carefully examined by the French chemists, Clement, Desormes, and Gay Lussac, but they all imagined that the hydriodic acid, which I have mentioned above, was nothing more than hydrochloric acid, till Sir H. Davy, with his usual penetration, inferred it to be new and peculiar.

Further examination has proved that the rich violet-coloured fumes deposit on the inside of the vessel scales of a bluish-black colour, and of a regular four-sided figure[1], which constitutes a simple substance not metallic nor inflammable, named *Iodine*[2], similar in many of its properties to chlorine. It has a very acid taste, and is a deadly poison, but, like other poisons, small doses of it were discovered by Dr. Coindet of Geneva, to be valuable as a medicine, more particularly in the treatment of goitre, and other scrofulous disorders[3], in most cases so difficult to remedy. Numerous compounds can be prepared from iodine and the other simple substances.

Discovery of Bromine.

Another simple substance, in some respects similar to iodine and chlorine, has been more recently discovered in sea-water. The first account of it, published by M. Balard of Montpelier, in August, 1826, excited great interest among chemists, who have since successfully investigated its properties, and combinations. M. Balard found it in sea-water in form of an acid, named *Hydrobromic* acid, which he supposed to be combined with magnesia. The discovery was made by adding chlorine to the water popularly termed bittern, remaining after the preparation of common salt, in which case the chlorine, uniting with the hydrogen of the hydrobromic acid, communicated an orange-yellow colour to the liquid. This was

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(1) Technically *Rhomboidal*.

(2) From the Greek ’ιωδης, “violet-coloured,” which is from ’ιον, “a violet,” and ἐιδος, “like.”

(3) I have given full directions for preparing these valuable medicines in my “NEW SUPPLEMENT TO THE PHARMACOPEIA.”

heated to the boiling point, when red fumes arose, which, on being passed through a tube surrounded with ice, were condensed into a blackish-red liquid, very corrosive, of a peculiarly strong taste, and virulently poisonous. Its smell is exceedingly disagreeable, on which account it has been termed *Bromine*[1], or brome. Like iodine and chlorine, it combines extensively with most of the simple substances.

Recapitulation.

Sea-water then appears, from the preceding brief notices, to be of a composition rather complicated, differing much in this respect from fresh water. It will aid the memory to enumerate the substances, which we have noticed in the above order.

Table of the substances contained in Sea-water.

Simple Substances.

Hydrogen Oxygen Chlorine Sodium Magnesium Calcium Sulphur Iodine Bromine	These, having resisted every means tried to decompose them, are considered to be simple substances.

Compound Substances.

	Composed of
Fresh Water	Hydrogen and oxygen
Soda	Sodium and oxygen
Common salt	Soda and chlorine
Magnesia	Magnesium and oxygen
Epsom salts	Magnesia and sulphuric acid
Sulphuric acid	Sulphur and oxygen
Lime	Calcium and oxygen
Hydrochloric acid	Hydrogen and chlorine
Hydriodic acid	Hydrogen and iodine
Hydrobromic acid	Hydrogen and bromine

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(1) From the Greek, βρωμος, "having a fœtid smell."

I have not mentioned the quantities of the several substances, because these vary in different waters. In some sea-water, for instance, no iodine has been detected.

COMPOSITION OF THE EARTHS.

In modern chemistry, the term "earth" is certainly very different from what was by the old philosophers reckoned one of the elements; for, instead of one sort of earth, there are now reckoned no fewer than ten. Two of these are magnesia and lime, which we have already seen, from the brilliant discoveries of Sir H. Davy, to be composed of the peculiar metals magnesium and calcium united with oxygen. What is in popular language termed earth, is a very variable compound, generally containing more than one or two of the substances, which are termed earths by chemists [1]. Of these lime is one of the most universally diffused next to clay, which we shall now examine.

Constituents of Clay.

The various substances popularly termed clay, such as pipeclay, brickclay, potters' clay, are all more or less mixed with flint-earth and iron, the latter of which imparts to them various colours, and causes them to

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(1) Full details respecting these will be given in the "ALPHABET OF AGRICULTURE."

emit a peculiar smell when breathed upon. It is not easy, in consequence of these mixtures, to separate the clay from them in a pure state; but it can be thus obtained from the well-known substance, *alum*, and if expense were not an object, it could be had very pure from those beautiful gems, the ruby, and the sapphire, which are almost pure clay.

This earth, when purified from all foreign substances, is white, easily reduced to powder, soft to the touch, is without smell, taste, or grittiness, and from its greedily drinking in moisture, it adheres with some force to the tongue. It will not dissolve in water, but it readily mixes with it. From its being usually obtained for chemical purposes from alum, it is termed *Alumina*[1].

Discovery of Aluminium.

Sir H. Davy was successful in proving to his own satisfaction, that alumina, like lime and magnesia, was formed of a peculiar metal united with oxygen; for he managed to get alumina to give up oxygen, though he could not procure enough of the metal for examination. The German chemist, Wöhler, has been more fortunate in obtaining this metal called *Aluminium* in quantity, and describes it as resembling platinum in powder, which, when burnished, takes the appearance of tin.

This metal, aluminium, then, is the basis not only

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(1) In old works, *Argil*, whence the term *argillaceous*.

of the greater portion of clay, but of many rocks and stones, such as basalt, and more particularly most sorts of slate.

Constituents of Flint Earth.

Perhaps flint earth is still more abundant in nature than clay, or, as we have termed it, alumina, and appears to have been intended by Providence to form the solid basis of the globe, to serve as a foundation for the original mountains, and to give them the hardness and durability which has enabled them to resist the various revolutions that the surface of the globe has successively undergone ; for this flint earth forms the basis of the enduring granite, as well as the more brittle freestone used in building. When these rocks accordingly have, in the course of ages, been partly crumbled by the action of frosts and rains, and worn down and swept away by streams and torrents, beds of pebbles, gravel, and sand, are the result (1), all, or in great proportion, made up of flint earth. The purest flint earth which occurs in nature is the well-known substance called rock crystal, of which our glass and crystal are only an artificial imitation, composed also of flint earth (2). Gun flints, and flints used for striking light, are flint earth, which is pure in proportion to its want of colour, the colouring matter being usually iron. All substances, indeed, which strike fire with steel, contain this earth; and it was from this property that Sir H. Davy, when an apprentice boy, laid the basis of his future fame, by discovering in wheat-straws the flint earth which he afterwards demonstrated to be a compound.

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(1) Interesting details will be given on this subject in the "ALPHABET OF GEOLOGY."

(2) This will be explained in the "ALPHABET OF GLASS-MAKING."

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Pure flint earth may be procured by heating a piece of rock crystal red hot, then throwing it into water, and afterwards reducing it to powder, which is light, white, rough, and without taste or smell.

Discovery of Silicium.

Sir H. Davy proved that flint earth, or, as it is termed by chemists, *Silica*[1], is a compound of oxygen and a simple substance called *Silicium*[2], which was procured at first in black particles, similar to the black lead used for pencils. It was afterwards, in 1824, obtained in a different manner by the celebrated Swedish chemist, Berzelius, who describes it as of a dark nut-brown colour, without the least trace of metallic lustre. It is not, therefore, now supposed to be a metal; for though in some respects it resembles metallic substances, it is probably more like pure charcoal[3], and one or two other simple substances.

A still greater uncertainty hangs over the next sub-

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(1) By older writers, *Silex*, and by some *Silicic acid.*

(2) By Dr. Thomson, *Silicon.*

(3) Technically, *Carbon.*

stance I shall here introduce, which, though it is not indeed an earth, comes into frequent chemical association with silica.

Fluorine.

In the stone called Derbyshire spar, from which the well-known chimney ornaments are manufactured, an interesting chemical substance is contained, first observed, in 1810, by Gay Lussac and Thenard, and since carefully examined by Sir H. Davy and Berzelius. The spar has been proved to consist of calcium, already mentioned as the metallic basis of lime united with a supposed simple substance, which has not hitherto been procured in a separate form, termed *Fluorine*[2]. When some of the spar is finely powdered and put into a leaden retort (a glass one will not do) with twice its weight of strong sulphuric acid, and heated so as not to melt the lead, a vapour comes over which must be introduced into a lead receiver, surrounded with ice, as it corrodes glass. Upon the sulphuric acid, which always contains some water, touching the spar, the water separates into its hydrogen and oxygen, the oxygen laying hold of the calcium and forming lime, which unites with some of the sulphuric acid, forming gypsum[3] or plaster of Paris. The hydrogen, on the other hand, lays hold of the fluorine and forms *Hydro-fluoric acid*, in vapour, which the ice

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(1) By mineralogists, *Fluor-Spar.*

(2) From the Greek φλυω, "I boil or ferment."

(3) Technically, *Sulphate of Lime.*

around the receiver cools down or condenses into a colourless fluid, which is exceedingly dangerous, as the least drop will instantaneously corrode the skin, and produce a deep ulcer difficult to heal. When poured on glass it boils violently, forcing itself into union with the silica in the glass, and the compound then produced rises in form of a colourless gas, the *Fluo-silicic-acid gas.*

Constituents of Heavy Spar.

The term "Spar" is rather vaguely applied to various mineral substances, of which the fluor-spar above examined is an instance, and I shall now give another in the mineral popularly termed Heavy Spar, which contains an earth of considerable interest in chemistry, termed *Baryta*[1]. It is common in lead mines, and, on account of its great weight, might deceive the ignorant unto a belief of its being lead, from the ores of which it was distinguished in 1774 by Scheele.

Discovery of Barium.

Sir. H. Davy, in following up his discoveries of sodium, calcium, and the other new metals, was led to examine baryta, which he succeeded, by means of the voltaic battery, in decomposing, and proved that, like lime, it is composed of oxygen united with a peculiar metal termed *Barium,* which is of a dark grey colour, and not so bright in lustre as cast iron. The baryta formed by this with oxygen is in the native state of

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(1) Formerly, *Barytes,* from the Greek *βαρυς,* "heavy."

spar, farther combined sometimes with carbonic acid, when it is called *witherite* by mineralogists, and is very poisonous; and sometimes with sulphuric acid, when it is called barytes. These, and other compounds of baryta, are of great use in many chemical processes.

Discovery of Strontium.

In 1791, Dr. Hope of Edinburgh, and the celebrated Prussian chemist, Klaproth, nearly about the same time, upon examining a sort of heavy spar found in the lead mines at Strontian in Argyleshire, and thence called *Strontia*[1], were led to observe that it differed considerably from baryta, with which it had previously been confounded. Sir H. Davy, in 1808, proved that this substance is composed of a metallic base, similar to that of heavy spar united with oxygen; and this base was named *Strontium* from the place where it had been first procured. It has since been found on the continent and in America. Its compounds are not poisonous like those of barium. It forms the main ingredient in producing the beautiful red fire, recently introduced in theatrical representations.

Constituents of the rarer Earths.

The most common earths which we have already examined are alumina, silica, lime, and magnesia; baryta and strontia are not so common, though more so than four others which we have now very briefly to notice.

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(1) Formerly, *Strontites*.

Glucina[1] was discovered by M. Vauquelin, in 1798, in emerald and beryl, and M. Wöhler, in 1828, succeeded in proving that it is composed, like the other earths, of oxygen, and the metal *Glucinium*, which is greyish black, and of a dark metallic lustre when burnished.

Yttria is named from Ytterby in Sweden, where this earth was first found by Professor Gadolin. M. Wöhler, in 1828, succeeded in proving that it is composed of oxygen and the metal *Yttrium*, the compounds of which taste sweet like those of glucinium, but it differs from this in its scaly texture and other particulars.

Thorina was very recently discovered by Berzelius, and named in honour of the fabulous deity Thor, from whom also we derive the name of Thursday, that is, Thor's day. Berzelius has been hitherto able to procure only a very small quantity of it, but enough to prove it to have a metallic base *Thorium*, which burns brilliantly in common air.

Zirconia was discovered in 1798 by Klaproth, in the stone called zircon or jargon brought from Ceylon. This earth when prepared is in form of a white powder without taste or smell, and somewhat harsh to the touch. Berzelius has succeeded in procuring its metallic base *Zirconium*, in the same way as he procured silicium.

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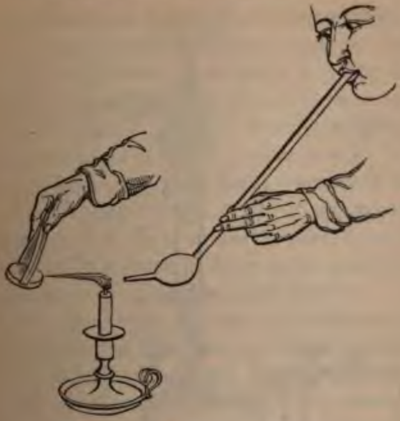
(1) From the Greek γλυκυς, "sweet," because some of its compounds taste sweet.

COMPOSITION OF MINERAL ORES.

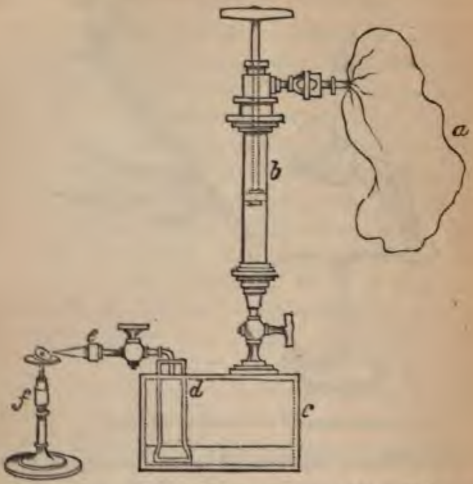
AMONG the forty-one simple substances, all considered to be metallic, some, such as gold, silver, copper, and iron, are occasionally found in nature, without being combined with any other substance; but this is by no means so common as to find them in the state of *Ore*. When in their simple metallic state, metals have a peculiar lustre, are not transparent, are capable of being melted or fused by heat without losing this lustre, and are capable, when melted, of mixing with one another in all proportions. Some of them are ductile, that is, they can be drawn out into wire or very thin leaves; and many of them are malleable, that is, they can be extended by hammering. At present, however, we have chiefly to notice the substances with which they are most commonly found combined in nature, and the means of expelling these to obtain the pure metal.

On a small scale, for the purpose of experiment, many of the substances combined with a metal in any one, may be expelled by means of a common lamp or candle, and the blowpipe which requires to be blown in a continued stream, and this of course is only to be acquired by practice, as it will not do to interrupt the stream of air by taking breath through the mouth. This must be accomplished by taking breath only through the nose, so as to keep a continued and uniform stream through the instrument, which is furnished near the end with a bulb for condensing the vapour of the breath.



Operation of the common blowpipe.

The difficulty experienced by some persons in blowing through the pipe in a continued stream, as well as the desire to produce a more intense flame, led to the invention of a more complicated instrument, in which the stream of air consists of a mixture of uncombined oxygen and hydrogen gas. These are forced, by means of a condensing syringe, into a box of iron or copper, from which they rush by means of this pressure through a tube with a very small bore. Here they are set on fire, and burn with a very intense flame. By this means several of the metals, such as platinum, which the heat of a blast furnace is incapable of melting, can be brought into a state of complete fusion.



Gas blowpipe. *a*, a bladder containing a mixture of oxygen gas and hydrogen; *b*, the condensing syringe; *c*, the copper box; *d*, a pile of circular pieces of wire gauze on the principle of the safety lamp, to prevent the gas in the box from exploding; *e*, the pipe where the flame is produced; *f*, the stand for the ore.

A jet of air from a double bellows may also form an excellent blowpipe.

When large portions of metal are to be fused, a furnace is indispensable.

Sulphur as combined with Ores.

One of the most common substances combined with metallic ores is sulphur, usually further combined with oxygen, and mixed with various other matters. The shining yellow matter sometimes seen on pieces of coal, and the gold-like little cubes in some sorts of roofing slate, are composed of sulphur and iron[1], and it may be expelled from the iron by bringing these compounds to a red heat in a close vessel. It is also procured from copper ore, and I observed it in abundance at the copper works of the Parys mountain in Anglesey, and at the alum works, near Bonn on the Rhine; but it is found in the greatest quantities near volcanoes, particularly Ætna and Vesuvius.

In the native state, sulphur is of a primrose yellow colour, brittle, has little taste, and almost no smell, unless it is rubbed or made hot, when its odour is peculiar, and by no means agreeable. The common roll sulphur, or stick brimstone, is not so pure as what is termed flowers of sulphur, produced by exposing impure sulphur to heat, when it rises[2] in fumes, which may be condensed by means of a proper apparatus in a manner somewhat similar to that by which lamp-black is procured. What remains in the vessel after this process of sublimation, is known in the shops under the name of *Sulphur vivum*, and is used externally for cattle, by veterinary surgeons.

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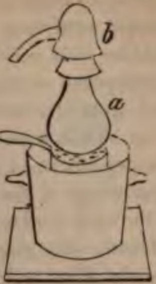
(1) Technically, *Sulphuret of iron*; in older works, *Pyrites*, from the Greek πυρ, "fire."

(2) Technically, *Sublimes*.



Apparatus for the sublimation of sulphur. *a*, an alembic, within the cupola *b*, of which the sulphur condenses that is sublimed by means of the burning charcoal in the chafing-dish, *c*.

The combination of sulphur with oxygen forming sulphuric acid, is of great importance in chemistry, and in manufactures; while it is this compound which is most usually found united with the metal.

Selenium as combined with Ores.

In the sulphur procured at Fahlun in Sweden, from its combination with iron, Berzelius, in 1818, detected a peculiar substance, which, on burning, mitted a strong smell similar to decayed horse ra-ish, and to which he gave the name of *Selenium*[1]. has since been examined by professor Stromeyer, öttingen, and by Rose of Berlin. This substance, though it has a metallic lustre, and is somewhat like lead, bears a nearer resemblance to sulphur in all its other properties, than to the metals, with which Berzelius was at first disposed to rank it. In the solid state it has no taste nor smell; but when brought to boil at the heat of 650 degrees, it forms a deep yellow vapour, smelling so strongly of decaying horse radish, that the fiftieth part of a grain will scent a large apartment.

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[1] om the Greek, σεληνη, "the moon," a very fanciful cal name.

The combination of selenium with oxygen forming *Selenic acid*, is very similar, according to Professor Mitscherlich, to sulphuric acid, and it is this compound which is most usually found united with the metals, such as lead, copper, silver, cobalt, and mercury.

Boron as combined with Ores.

In the hot springs of Italy, as well as in combination with several mineral substances, there is found a peculiar acid, whose union with soda has long been known to workers in metal, under the name of *Borax*. This acid was proved by Sir H. Davy, in 1807, to be composed of oxygen combined with a substance which he was unable to decompose, and to which he gave the name of *Boron*(1). It has since been procured in more considerable quantities than at first, by Gay Lussac and Thenard, and by Berzelius, who describe it to be a dark olive-coloured substance without taste or smell, taking fire at 600 degrees, and in that case combining with oxygen, and forming *Boracic acid.*

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(1) From the Greek, βορος, "voracious."

Carbon as combined with Ores.

We have already seen, when treating of the composition of the common air, that it contains a small proportion of the gas termed carbonic acid, and that this gas is a compound of oxygen and pure charcoal, or, as it is called by chemists, *Carbon.* This acid is extensively combined with minerals, not only in marble, limestone, marl, chalk, basalt, coal, and the spars, but in the ores of many of the metals, while it has been proved to be the only substance in the diamond, which is pure carbon. It is too expensive, however, to use diamonds for obtaining pure carbon for chemical purposes, and it may be procured very pure by burning starch or sugar in close vessels to a red heat, or by passing the vapour of turpentine or spirits of wine, through red hot tubes. Carbon, somewhat less pure, but sufficiently so for many purposes, may be obtained by treating wood in the same way as the starch or sugar.

arbon is hard, brittle, and appears to be black,
h Sennebier says it is rather a very deep blue,
nce he accounts for the green colour of plants
e dark blue carbon in the pulp of the leaves,
n through the yellowish membrane of the
. It is worth remarking, that, so long as

"ALPHABET OF BOTANY," page 68.

it is excluded from access to the air, that no intensity of heat is capable of producing in it any change. It is no less singular that though the diamond, or natural pure carbon, is so close-grained, if I may use the term, pure artificial carbon weighs somewhat heavier than diamond.

Metals as combined with other Substances.

It may be useful to give here a brief glance at some of the more remarkable properties of the metals, which I cannot spare room to enumerate individually, and with this view I shall class their leading properties, rather than the metals themselves.

With respect to weight, the metals known to the ancients, were all rather heavy, gold being the heaviest, and tin the lightest, while silver and copper hold a sort of medium ; but modern discovery has found in platinum, a metal still heavier than gold, and in palladium one heavier than lead ; while the new metal sodium, already mentioned, is lighter than water, on which it will swim.

The metals which are malleable, that is, which can be extended by hammering, are gold, platinum, silver, palladium, mercury when frozen, copper, iron, lead, tin, zinc, and, it is said, nickel. Gold is superior in malleability to all the rest, the leaf gold sold in little books being so thin that five grains cover a surface of 272 square inches, while the thickness of the leaf does not exceed $\frac{1}{282020}$ of an inch.

The same property renders metals ductile, that is, capable of being drawn into wire. Iron, which is by no means so malleable as gold, may thus be made into wire not thicker than a human hair; and a grain of gold surrounded with silver, was drawn out by Dr. Wollaston to the extent of 700 feet, and was only $\frac{1}{30000}$ of an inch in thickness.

As to strength or tenacity, M. Guyton Morveau found by experiment, that an iron wire will sustain more than double the weight of one of platinum of the same thickness, and more than twenty times the weight of one of lead. Copper wire is about one half the strength of iron wire.

All the metals melt or fuse when exposed to heat; but individually vary much in this respect. The heat of a forge will not fuse titanium, cerium, osmium, iridium, rhodium, platinum, and columbium; but they may be melted by the gas blowpipe, which is also required to melt thoroughly, molybdenum, uranium, tungsten, and chromium, though they may be partially fused in the forge. It requires a red heat to fuse silver, copper, gold, cobalt, iron, manganese, nickel, and palladium, while a lower degree of heat will fuse cadmium, antimony, zinc, arsenic, tellurium, lead, bismuth, tin, and the metallic bases of the earths.

When the heat necessary to fuse them is increased, some of them may be made to boil, and it is probable all of them may be by sufficient heat raised in the form of vapour, which, in some instances, returns on cooling to the metallic state, and in others forms permanent compounds with oxygen, or some other gas.

discovery has added to these a great number of others, and it is not improbable their number may be still farther increased by future research.

Characteristics of the Alkalies.

Alkalies change the purple colour of many vegetables to green, such as test paper stained with litmus, tincture of violets, or infusion of red cabbage; the reds to purple; and the yellows to brown, such as test paper stained with turmeric. If the litmus paper, or other purple colour, have been reddened by any acid, an alkali will again change this red to purple. These effects, upon colour, are not influenced by the presence of carbonic acid gas[1].

The alkalies have an acrid taste, and most of them a urinous smell. They are corrosive to the skin, and when mixed with oils, or fat, they form soap, and they dissolve readily in water, and largely in spirit of wine. They combine with acids, forming compounds, termed salts, or neutral[2] salts, because they are neither acid nor alkaline.

Characteristics of the Alkaline Earths.

Some of the earths already noticed possess several properties in common with the alkalies, among which are lime, baryta, and strontia. These are caustic, soluble in water, act, like the alkalies, on vegeta-

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(1) More minute details will be given in the "ALPHABET OF TEST CHEMISTRY."

(2) From the Latin *Neuter*, "neither."

ble colours, and in this latter quality, magnesia agrees, but it is mild and insoluble in water. None of the alkaline earths, however, will act upon vegetable colours, nor dissolve in water after combining with carbonic acid gas, a circumstance which distinguishes them from the genuine alkalies.

Constituents of Potass.

The term potass originated from the alkali so named, being procured by burning vegetables to ashes [1], in large iron pots. It is, by some, called *Potassa*, for uniformity of termination. It is found in the ashes of all inland plants, but different species vary considerably in the proportions of potass which they contain. Boxwood, for example, and aspen, contain only sixty or eighty pounds of potass in every thousand pounds weight of the wood; while the stalks of sun-flower, fumitory, or wormwood, contain from three hundred and fifty to seven hundred and fifty pounds in every thousand [2].

The articles sold in the shops, under the names of potash and pearlash, both consist of potass combined with carbonic acid gas, and mixed with various impurities. We may obtain pure potass by burning cream of tartar in a vessel, termed a crucible, dissolving what remains in water, and filtering it; then boiling it with a quantity of quicklime, and drying it in a loosely covered silver capsule, till it flows like

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(1) Technically, *Incineration.*

(2) See "ALPHABET OF SCIENTIFIC GARDENING."

oil [1], and then pouring it out on a clean iron plate. The solid white plate, thus procured, must be immediately broken to pieces, and kept in a phial closely stoppered.

Discovery of Potassium

The late Mr. S. Parkes, in 1805, suggested that the alkalies were probably compound substances, and early in October, 1807, Sir H. Davy proved this by his brilliant discovery of the metallic base of potass, which he named *Potassium*. The apparatus with which the discovery was made, is figured above, page 40. In 1808, Gay Lussac and Thenard procured it in larger quantity by burning iron turnings to a white heat in a curved gun-barrel, melted potass being brought in contact with these, and the air excluded, the potassium collected in the cool part of the tube. M. Curandau, in the same year, procured it by burning potass with charcoal in a similar tube. M. Brunner, more recently, has procured 140 grains of potassium by mixing intimately eight ounces of fused potass, six ounces of iron filings, and two ounces of charcoal, and heating them to redness in an iron bottle. M. Wöhler has successfully tried a similar process by using charcoal alone without the iron.

Potassium has very much the appearance of quicksilver, and is considerably lighter than water. When is placed upon water, accordingly, it swims; and,

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(1) Popularly, *Oil of tartar*.

decomposing it, even in the state of ice or snow, it lays hold of its oxygen, with which it combines, forming potass, while the hydrogen, thus set free, takes fire, and burns brilliantly, realising the miracle of producing fire from ice, said to have been performed in the fifth century by St. Patrick [1].

The constituents of soda, and discovery of sodium, which would fall to be noticed here, have been already introduced under SEA WATER.

Constituents of Lithia and Discovery of Lithium.

In 1818, M. Arfwedson, a Swedish chemist, discovered a new alkali in a mineral called petalite, and it has since been found in mica, and several other minerals, and by Berzelius in the waters of Carlsbad in Bohemia. It has been termed Lithia [2], and is distinguished from potass and soda by its solution in spirits of wine, burning with a red flame ; and from the alkaline earths, by its compound with carbonic acid when dissolved in water, staining turmeric paper brown. *Lithium*, the metallic base of Lithia, was discovered by Sir H. Davy. It is white, and similar to sodium.

Constituents of Ammonia.

From time immemorial, a substance called *Sal ammoniac* has been prepared in the district of Ammonia,

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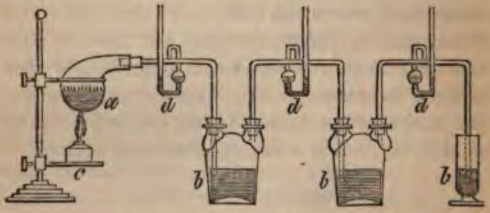
(1) " De glacie produxit ignem," says his biographer, Jocelin.

(2) From the Greek λιθειος, " stony."

between Libya and Egypt, from the soot formed by burning camels' dung. This, which is now manufactured in Europe by different processes to a considerable extent, is found to consist of hydrochloric acid, and the alkali called *Ammonia*, first observed, it would appear, by Dr. Priestley, and well known by the popular name of hartshorn, or spirit of hartshorn.

Ammonia may be procured by mixing two parts of fresh burnt lime in powder, with one part of powdered sal ammoniac; putting the whole into a glass retort, with a tube to communicate with a glass receiver containing water; and applying to it the heat of a lamp. The hydrochloric acid will thus be expelled from the sal ammoniac, and combine with the quicklime, setting the ammonia free, which will pass into the receiver in form of an invisible gas, and will mix with the water.



Preparation of Ammonia:—*a*, the retort with the sal ammoniac and quicklime; *b*, receivers containing water; *c*, the lamp, *d*, *d*, *d*, safety tubes to prevent explosions.

When it is required to obtain the gas by itself, it must be collected in a receiver over quicksilver. A beautiful experiment is made by introducing into a receiver, containing this ammoniacal gas, a portion of carbonic acid gas; for though both are previously invisible, when they combine, thick white fibre-like flakes, of a silvery appearance, are produced.

The celebrated French chemist, Berthollet, discovered that ammonia is a compound of three parts by bulk of hydrogen gas, and one part of nitrogen gas; but when these proportions are mixed and combined by passing through them an electric spark, they only form two parts by bulk. Sir H. Davy and Berzelius made some experiments to prove that ammonia, like the fixed alkalies, has a metallic base, *Ammonium;* but though this seemed plausible, it was not satisfactorily proved. Here the matter at present rests.

Discovery of the Alkaloids.

About the year 1803, Derosne procured a peculiar substance from opium; about the same time Dr. A. Duncan, of Edinburgh, obtained a peculiar substance from Peruvian bark; and in 1804, Seguin detected a different substance in opium from that of Derosne; but none of these attracted much attention for several years. Sertürner, a Hanoverian chemist, who had as early as 1803 discovered in opium the same substance as that mentioned by Seguin, published, in 1816, an essay, to announce that this substance is alkaline, and from that period to the present moment much interest has been excited respecting these new substances, which have rapidly multiplied to the number of nearly thirty, though not more than eight or ten of them have been sufficiently investigated, to warrant us to pronounce, in all cases, upon their characteristic differences or identity.

They possess the alkaline character of combining with acids, and forming neutral salts; while most of them render vegetable yellows brown, and vegetable blues green. They differ, however, from the alkalies above enumerated, in the remarkable circumstance of containing four instead of two simple substances, all of them which have been sufficiently examined containing oxygen, hydrogen, carbon, and nitrogen. On account of this difference of composition, and of some other circumstances, they have been called *Alkaloids* (1).

The most celebrated of these alkaloids is that procured from Peruvian bark, different from the one first observed by Dr. A. Duncan, and discovered by MM. Pelletier and Caventou; at first called quinine, but now *Quinia*. This, as well as the alkaloid procured from opium by Sertürner, and since so well investigated by M. Robiquet, and termed *Morphia*, are very valuable as medicines (2). Like most other novelties, however, the power of these was at first much overrated; and though they certainly produce wonderful effects, *Morphia* will not always remove pains, nor will *Quinine* always cure agues.

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(1) From the Arabic, *Alkali*, and the Greek ἐιδος, "likeness."

(2) I have given the methods of preparing all these alkaloids, with their medical doses, in my "NEW SUPPLEMENT TO THE PHARMACOPŒIA."

COMPOSITION OF ACIDS.

We have already seen that oxygen was so named by M. Lavoisier, on account of one of its chief properties being that of forming an acid by combining with some other substance, such as carbon, or sulphur; and oxygen was for some time held by chemists to be the exclusive " acid-generator," as the name imports. Subsequent discovery proved this to be incorrect, for we have already seen, that there is no oxygen in hydrochloric acid. It was known, indeed, even to M. Lavoisier, that oxygen did not always produce an acid in its combinations, more particularly in the remarkable case of common water, and in that of most of the metals, arsenic, chromium, and tungsten being with some others exceptions to this; but he had no idea of oxygen by combining with a metal forming an alkali, or an earth, as in the case of potass and lime, whose properties are so very different from those of acids.

The term "acid [1]" means "sour," and acids, with few exceptions, such as arsenic acid, are sour when liquid or dissolved in water; but some of the acid gases do not, while gaseous, taste sour, nor do they then redden the blue colours of vegetables, such as litmus paper, which all liquid or dissolved acids more or less do.

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(1) In Latin, *Acidum*, " sour," or " sharp," from the Greek ἀκη, " a sharp point."

It is this action on colours which distinguishes most acids readily from alkalies. The chief property, however, of acids is their forming neutral salts. There is not room in a small work like this to go into particulars of all the acids, of which I have elsewhere[1] enumerated nearly 150, and treated of them in detail; but I shall introduce one or two of the most interesting by way of illustration. Dr. Ure has arranged the acids in four classes: 1, Those containing oxygen; 2, Those containing hydrogen; 3, Those containing neither oxygen nor hydrogen; and, 4, Organic acids of animal or vegetable origin. I shall select examples from each class.

Constituents of Nitric Acid[2].

The strong acid, first prepared in the 13th century, by Raymond Lully, has been long known in the arts, under the name of *Aquafortis*, which is Latin for "strong water." It was discovered in 1785, by the Hon. Mr. Cavendish, to be composed of oxygen and nitrogen; and it was from this indeed that the term nitrogen originated. This may be proved by mixing together seven parts of oxygen gas with three of nitrogen gas in a glass vessel, with a little water over quicksilver, and passing through the mixture a succession of electric sparks. This will force the two gases into combination, when they will gradually diminish in bulk, and will render the water strongly acid. When a

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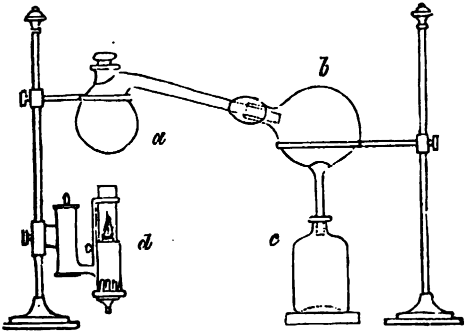
(1) "NEW SUPPLEMENT TO THE PHARMACOPŒIA," 3rd edit.

(2) In Latin, *Acidum nitricum*.

little pure potass is at first put into the glass, instead of an acid being formed, there is procured what is termed nitre [1], or saltpetre, a compound of potass and nitric acid.

It is from nitre, that nitric acid is manufactured on the large scale, by putting one hundred parts of it, previously freed from water by drying, into a glass retort, and pouring over it sixty parts of strong sulphuric acid. The beak of the retort, luted with glazier's putty to what is called an adopter, is passed through another tube into a large glass bottle, containing twenty parts of water. The heat of a lamp, or of a sand bath, is then applied to the retort, when



Preparation of nitric acid:—*a*, the retort containing the nitre and sulphuric acid; *b*, the adoptor; *c*, the bottle with a little water; *d*, the lamp.

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(1) Technically, *Nitrate of potass;* in Latin, *Nitras potassæ*.

the sulphur of the sulphuric acid leaves it, and lays hold of the potass in the nitre, while the oxygen and nitrogen gases thus set free, unite and pass into the adopter in the form of red or orange fumes, which will condense and mix with the water in the bottle.

The red or orange fumes which come over, and which become colourless as the process advances, but redden again towards the close, consist of the nitric acid, which is itself transparent, and what is termed nitric gas [1], which is also transparent; but when it meets with common air, or oxygen, it becomes coloured red, by forming nitrous acid with the oxygen. Those reddish fumes may be very easily shown, by putting a piece of clean copper, such as a penny-piece, into a glass, and pouring over it some nitric acid, when the fumes will rise, which, by a different process, may be obtained in a liquid form. These fumes are suffocative, and the acids, both the stronger nitric and the weaker nitrous, are poisonous when taken into the stomach, by corroding its membranes, and producing violent inflammation and torturing pain. With smaller proportions of oxygen, two other acids are formed, the hyponitric, and the hyponitrous acids.

Nitrous Gas [2], popularly Laughing Gas.

Another gas, popularly well known under the name of the laughing gas, may be formed by exposing

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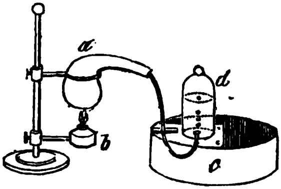
(1) Technically, *Deutoxide of Nitrogen*; by Sir H. Davy, *Nitric oxide.*

(2) Technically, *Protoxide of nitrogen*; by Sir H. Davy, *Nitrous oxide.*

liquid nitric oxide for some days to the action of iron filings, when half the oxygen goes over to the iron, and combines with it, leaving the gas free; or, it may be rapidly and easily procured by putting into a glass retort some of the compound of ammonia and nitric acid[1], and placing it over a lamp, when brisk effervescence will be produced, the gas will come over, and may be collected in the usual way over hot (not cold) water, or quicksilver.



Preparation of Nitrous, or Laughing gas. *a*, the retort, containing the compound of ammonia and nitric acid; *b*, the lamp; *c*, trough containing hot water, or quicksilver; *d*, the glass receiver.

Sir H. Davy discovered, that by breathing this gas out of a bladder, or other convenient gas-holder, it excites a vivid flow of ideas, and an irrepressible tendency to laugh, dance, and other muscular exertions, without any of the depressing feelings which follow intoxication. Some of the first who tried it, said they felt as if "bathed in delight."

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(1) Technically, *Nitrate of ammonia.*

Constituents of Arsenious Acid.

The noted poisonous substance, popularly known by the name of arsenic[1], is a combination of the metal named arsenic with oxygen, possessing the usual characteristics of an acid, such as reddening vegetable blues, which may be shown by sprinkling the powder on moist litmus paper, though it does not appear to taste sour, but sweet, a circumstance which has occasioned cases of poisoning, by children mistaking it for white sugar. As in the preceding case, metallic arsenic combines with oxygen gas in two proportions, producing two acids, one called the arsenic, and the other the arsenious, acid. The arsenious acid is what is popularly termed arsenic, and may be obtained by burning metallic arsenic in oxygen gas. When it is exposed to a heat of 383° it rises in vapour, which sometimes smells of garlic, though this is not the smell of the acid, but of the metal. Although a violent corrosive poison producing inflammation, it is, like many other poisons, a valuable medicine in small doses[2]. It is more efficacious, for example, in curing agues, than anything hitherto discovered, not excepting even quinine itself; and is the basis of the nostrums called Fowler's Solution, and the Tasteless Ague Drop.

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(1) In Latin, *Arsenici oxydum album.*

[2] See "NEW SUPPLEMENT TO THE PHARMACOPŒIA" for ses, &c.

Constituents of Hydrocyanic Acid.

Among the most powerful poisons hitherto discovered, is the acid, popularly termed the *Prussic acid*, because it is frequently made from prussian blue[1]. So deadly is this poison, that Professor Scharinger, of Vienna, having prepared some concentrated and pure, and spread a portion of it over his arm, died very soon after in consequence : a rod dipped into it, and applied to the tongue or the eyeball of any animal, causes it to fall dead almost as soon as if it were shot. It is consequently dangerous to prepare it, as well as to possess it, in the strong state.

In a weaker state, that is, diluted with water, this compound has long been known, Macquer first discovered that prussian blue could be decomposed by alkalies, and its iron separated from a principle which Bergman considered to be an acid. M. Sage, in 1772, announced it as an animal acid, and the celebrated Scheele concluded that it consisted of carbon and ammonia. In order to obtain it, Scheele mixed four ounces of prussian blue with two ounces of the red compound of oxygen with quicksilver[2], prepared by means of nitric acid, boiling the mixture in twelve ounces by weight of mercury, till the whole became colourless ; afterwards filtering the liquor, and adding

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(1) Technically, *Ferrocyanate of Peroxide of iron.*

(2) Technically, *Peroxide of mercury.*

to it an ounce of clean iron filings, and six or seven drachms of sulphuric acid. A fourth of this drawn off by distillation, will be hydrocyanic acid, contaminated with a little sulphuric acid, and containing six times its bulk of water. This weaker acid is at present employed as a medicine.

The hydrocyanic acid is contained in bitter almonds, and in the kernels of most stone fruits, as well as in the leaves of cherry laurel, the water of which is known to be poisonous.

It has been shown to contain no oxygen; but to be a compound of hydrogen and a peculiar compound gas, termed *Cyanogen*[1].

Discovery of Cyanogen.

In 1815, M. Gay Lussac discovered the gaseous base of hydrocyanic acid, by heating in a small glass retort a quantity of the compound of quicksilver, with prussian blue[2]. In these circumstances, it first becomes black, then liquid, and at length a gas is evolved, which may be collected over quicksilver. This is cyanogen, thus named by its discoverer, because it forms prussian blue when combined with the red compound of oxygen and iron[3]; but, as Dr. Ure well remarks, it is not only the producer of blue, bu

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(1) From the Greek *κυανος*, "blue," and *γενναω*, "I generate," meaning, "blue-generator."

(2) Technically, *Cyanuret of mercury*; formerly, *Prussiat* *mercury.*

(3) Technically, *Peroxide of iron.*

combined with other metals produces white, red, and green.

Cyanogen gas is without colour, and has a strong, penetrating, disagreeable, even a dangerous odour, and is very inflammable, burning with a beautiful bluish flame blended with purple. By mixing cyanogen with oxygen gas, and exploding the mixture, M. Gay Lussac discovered that it is compounded of its own bulk of nitrogen, and twice its volume of the vapour of carbon (not carbonic acid gas).

Hydrocyanic acid then is a compound of hydrogen, carbon, and nitrogen. The cyanogen, however, also combines with two proportions of oxygen, forming cyanic acid discovered by Serullas, and cyanous acid discovered in two varieties by Wöhler and Liebig. The compound of cyanogen and iron united with hydrocyanic acid[1] forms an interesting compound, termed *Ferrocyanic acid.*

Discovery of Chloriodic Acid.

In 1814, Sir H. Davy, and about the same time M. Gay Lussac, discovered a peculiar compound, by admitting chlorine in excess to known quantities of iodine in vessels exhausted of air, and repeatedly heating the sublimate. By this means, iodine takes up less than one third of its weight of chlorine, and the result is an acid, which is very volatile, of a bright yellow colour, but when fused, or brought into

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(1) Technically, *Cyanuret of iron;* formerly, *Prussiate of iron.*

the state of gas, it is bright orange. It does not appear, however, that the exact composition of this chloriodic acid is yet ascertained, though it seems not to contain either oxygen or hydrogen.

Constituents of Acetic Acid.

The well-known liquid, vinegar, is very impure, diluted, acetic acid[1], which may be obtained pure by distilling common vinegar, when it is procured along with some water that may be got rid of by freezing; or by putting two parts of the compound of potass with vinegar[2], and one part of the strongest sulphuric acid into a glass retort, and distilling the mixture into a receiver surrounded by cold water, pure concentrated acetic acid may be procured.

This acid is found in many vegetable and animal substances, such as in sweat, in urine, according to Dr. Ure in fresh milk, in the stomach of persons affected with indigestion, and in all vegetables in a state of fermentation. It is procured in quantities from wine, beer, sugar, and more recently by distilling wood, in which case it is termed *Pyroligneous*[3] acid. The following figure, from Parkes's valuable "Chemical Essays," will show the method of conducting this manufacture.

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(1) In Latin, *Acidum aceticum.*

(2) Technically, *Acetate of potass.*

(3) From the Greek πυρ, "fire," and the Latin, *Lignum,* "wood."

glass of water, it is refreshing and tonic, which proportions, when a student of medicine, I often used as common drink, before I ever heard of its being poisonous. It requires about half an ounce to prove dangerous or fatal.

Oxalic acid exists in sorrel, rhubarb stems, and several other vegetables ; but is manufactured from sugar, by dissolving one part of refined sugar in four parts of nitric acid, and slowly distilling off about one part, when the oxalic acid remains in the retort, and is obtained in crystals by evaporation. Dr. Thomson, by very careful experiments, found, that nine grains of oxalic acid in crystals contain four grains and a half of water, three grains of oxygen, and one grain and a half of carbon.

COMPOSITION OF SALTS.

I HAVE stated above, that what are termed salts, or neutral salts, are composed of acids and alkalies, the term having originally been given to sea-salt (1) exclusively. Almost all the salts are solid, and though their constituents are colourless, many of them are coloured, and several are colourless when the constituents are coloured. Almost all of them, when dissolved, have a peculiar taste ; but few of them have any smell. I have already gone with some minuteness into the composition of common salt, and have incidentally mentioned several others; but it would take more space than the whole of this little volume, to detail the properties of all the numerous salts. I shall therefore content myself here with noticing some which Berzelius has rendered interesting.

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(1) In Latin *Sal*, from the Greek ἅλς, "the sea," or "sea salt."

Constituents of Sulpho-Salts.

The compounds, to which Berzelius has given the name of *Sulpho-Salts*, have a metallic base, combined with a double proportion of sulphuric acid[1]. If orpiment[2], for instance, which is a compound of sulphuric acid and arsenic, be dissolved in solution of potass, the oxygen of a portion of the potass unites with arsenic, forming arsenious acid, and the potassium thus set free unites with sulphur[3]. The arsenious acid again thence produced, unites with the potass[4] that remains undecomposed, while the compound of potassium and sulphur unites with the orpiment that remains undecomposed. Dr. Turner, however, thinks this may be explained by supposing the oxygen of the arsenious acid here generated to be derived, not from the potass, but from the water in which it is dissolved. If this be correct, the very existence of a sulpho-salt in solution will be disproved.

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(1) Technically, *Double sulphurets.*

(2) Technically, *Sulphuret of arsenic.*

(3) Technically, *Sulphuret of potassium.*

(4) Technically, *Arsenite of potass.*

TEXTURE OF SUBSTANCES.

THE word "substance[1]" was invented by the ancient philosophers to signify a sort of framework or scaffolding, on which they fancied all material things to rest. The yellow colour of a piece of gold, together with its weight, hardness, and form, and other properties, were not, in their opinion, the substance, but rested upon it, while the substance itself was invisible, inscrutable, and, in a word, they did not know what it was, nor could they even prove its existence, no more than they could prove the existence of another imaginary thing called *matter*, which they said had length, breadth, thickness, and impenetrability; though nobody ever pretended to have seen or felt this fanciful thing called matter, apart from wood, metal, stone, or the like.

Even the inductive philosophy of Lord Bacon, and the plain common sense which it has diffused through modern philosophy, have not succeeded in banishing altogether the fanciful views built upon these theoretical nothings termed substance and matter; as one proof of which, I may refer to the commencement of Dr. Arnott's "Physics," in many respects the best, because the plainest, philosophical work in any language, where the old doctrine of matter appears nearly as it did two thousand years ago.

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(1) In Latin, *Substantia*, from *sub*, "under," and *stans*, "standing;" in Greek ὑποκειμενον, "under-lying."

By some nicely refining writers, the old fancy of *substance* being the framework of all things, was modified into what they termed *essence*[1], and now the very same notion is expressed by the term *nature*[2]. Accordingly we are told in most books, that "the *nature* of light or heat is unknown," meaning plainly by "nature" the fanciful nothing, otherwise termed substance or essence; for the properties of light and heat are as well known as those of water or iron. The same fanciful dreams have given rise to the impertinent discussions whether light, heat, &c., be material; that is, whether they have a frame work of the long, broad, thick, impenetrable, and fanciful nothing, which nobody ever saw or felt, called *matter*[3]; or whether they be mere motions, existing, of course, without any thing being moved, and like no other motion. The impertinence and folly is carried further by those who argue for light, heat, &c., being supported on this fanciful framework, as they hesitate not to call them *fluids*, though they cannot be shown to possess one property in which they in the least resemble water or other fluids. It is surely high time that all such visionary stuff were banished from sciences pretending to be supported on rational proofs; yet I scarcely know a single scientific work that is not more or less contaminated therewith.

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(1) In Latin *Essentia*, ' being-in," a word invented by Cicero.

(2) In Latin, *Natura*, "what has been born or produced;" om the Greek γεννaω, "I generate."

3) This subject will be further detailed in the "ALPHABET OF ERN PHILOSOPHY."

I have used the term "substance" throughout this work as meaning any chemical article, simple or compound, without any reference to the old fancy, and I shall now use it in the same way. "Texture" is here meant to express the state of compactness or looseness in which the particles composing a substance are found, as well as the regular or irregular arrangement of such particles. The state of compactness or looseness will now be shown to depend on what is called *heat*[1], and the arrangement of the particles on what is termed *polarity*.

EFFECTS OF HEAT ON TEXTURE.

WATER, our first example of a compound substance, is well known under three states of texture, solid, fluid, and gaseous, popularly called ice, water, and steam. Now in all these three states, so far as chemistry can ascertain, there is no difference whatever in the proportions of the oxygen and hydrogen composing it, and the only proved difference is in the varying proportions of heat. With respect, however, to oxygen and hydrogen, we can confine them in our receivers and estimate their bulk by measurement and their weight by the balance; while heat cannot be so weighed and measured. The circumstances founded on personal feeling of the air being sometimes

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(1) Technically, *Caloric*.

hot and sometimes cold are exceedingly vague; often depending on the individual, who may feel cold when another may feel warm. This difficulty has been in part got over by the invention of an instrument, originating in its improved state with Sir Isaac Newton, by which the quantity of heat is estimated, not by weight or measurement, but by degrees. This is called the *Thermometer*[1], and is founded on the principle, that quicksilver, spirits of wine[2], or whatever else is used in constructing the instrument, expands or contracts in proportion as there is more or less heat present. The instrument is placed first in freezing water, or rather in melting ice or snow, when the expansion of the fluid is marked, and then it is placed in boiling water, when the expansion is again marked. The distance between these two points, on a fixed scale, is then divided into degrees—different, unfortunately, in different countries. In Britain we use the Dutch scale of Fahrenheit; in France they now use the Swedish scale of Celsius, called the Centigrade[3]; while in most other countries they use the French scale of the celebrated naturalist Réaumur. The following figure, from the "Companion to the Almanac," gives a comparison of these three thermometers. The point marked 0° is termed *zero*[4].

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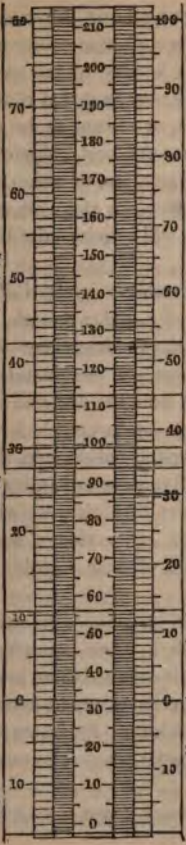
(1) From the Greek *θερμη*, "heat," and *μετρον*, "measure," meaning "heat-measurer."

(2) Technically, *Alcohol*, an Arabic word.

(3) From the Latin, *Centum*, "hundred," and *Gradus*, "degree."

(4) *Zero* is Arabic for "nothing."



Water boils when the barometer stands at 30 inches.

174° Spirits of wine boil.

° Highest heat of
he sun's rays ob-
served at London.

142° Bees' wax melts.

127° Tallow melts.

Fever heat, as usually marked.

Blood heat.

Highest heat of
he air at London.

Summer heat.

Temperate.

48° Usual heat of springs.

Water freezes.

20° Strong wine freezes.

ro, greatest cold
observed in Eng-
and.

hermometer, marked with the three scales of Fahrenheit in *centre, the* Centigrade on the right, and Réaumur on the left.

This instrument affords the means, then, of estimating the degrees of heat communicated to it, but nothing more, for it does not tell us anything with respect to the degrees of heat that remain as permanent in fluid water, ice, or steam, as do their oxygen and hydrogen; because the heat I allude to, is insensible [1], and fixed in the water, ice, or steam, as a portion of its texture or substance,—a singular, and important circumstance which will require brief illustration.

Insensible or confined Heat.[1]

It is a matter of popular remark, that the air feels colder when a thaw commences than it had done during severe frost,—a circumstance which can be readily explained from the doctrine of heat combining with substances in an insensible form; for as it requires heat to expand substances, the things frozen, such as water, will require a quantity of heat to render them fluid, and for that purpose will lay hold of it from the air and other things contiguous, which, being thus robbed of their sensible heat, must feel colder.

That the water, on being converted from solid ice into a fluid, has then taken in a considerable portion of heat, and kept it confined in an insensible state, can be proved by numerous experiments. Let a piece of fresh burnt quicklime, for instance, which, on trial with the thermometer, shows the same degree of heat

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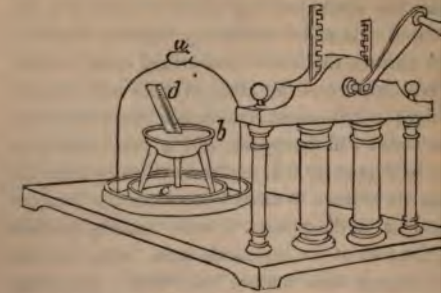
(1) Technically, *Latent* or *Specific Caloric.*

as the air, be sprinkled with water as cold as it can be procured. It will immediately begin to hiss as if you had thrown the water on burning coals, a white smoke will arise, and the piece of lime will crumble to powder; but the most remarkable circumstance is, that the water will disappear, and a great degree of sensible heat may be felt, derived evidently from the water, as its texture is more loose than the compact lime, and as it disappears, it must actually become dry by the loss of its insensible heat, both the lime and it changing their texture the while. The white smoke consists of a small portion of water converted into steam by the evolution of the sensible heat, and some of the fine particles of the lime mixed therewith.

When the fluid texture of water is changed into the solid texture of ice, there is a similar evolution of sensible heat, though not so obvious as in the instance of slaking quicklime. This can be most strikingly exhibited by the effect of evaporation, that is, converting a portion of the water into gaseous vapour, which, requiring a considerable quantity of heat for this change of texture, carries it off from the rest of the water, and being thus robbed of the heat required for the fluid texture, it is converted into ice. The experiment contrived by Professor Leslie, of Edinburgh, shows this in a beautiful manner: it is founded on the principle of water evaporating more rapidly when the pressure of the air is removed, and on sulphuric acid greedily absorbing moisture from the air.



Sir John Leslie's experiment of freezing water by ev
tion :—*a*, the receiver of an air pump exhausted of ai
saucer containing the water to be frozen, supported on a
c, a vessel containing strong sulphuric acid ; *d*, a therm
to mark the degrees as the experiment proceeds.
minutes only are required to freeze the water in the sau

Another easy experiment, illustrating the
thing, is performed by dissolving as great a qu
as possible of Glauber's salts[1], a compound of s
ric acid and soda, in a phial nearly full of
bringing it to boil over a lamp, and then cork
tight, taking care not to shake the phial till it be
cold. On then removing the cork, the flui
become solid, and at the same time will throw
insensible heat, which may be felt by the hand
outside of the phial.

It appears to hold universally, that a su
degree of heat will convert the most solid sub
into a soft or fluid state, and from that, into a

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(1) Technically, *Sulphate of Soda.*

vapour; while on the contrary, the abstraction of heat, if carried far enough, will convert all vapours into liquids, and all liquids into solids; a certain portion of heat always becoming insensible in proportion as the texture of the substance becomes less compact. This insensible heat always appears again in the sensible form, as the texture of the substance becomes more compact.

A tin saucepan set on a brisk fire, without water, would soon melt by the heat supplied from the fire entering into the tin, changing its texture, and becoming in part insensible; but if the saucepan contains water, the heat supplied by the fire to the tin will be successively carried off by the water, whose texture it will change into steam, so that the tin can never retain enough of the supplied heat to change its texture, as long as there is any water left to carry it off.

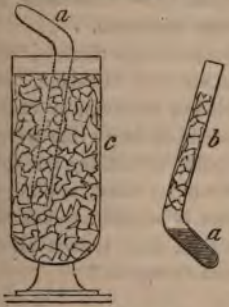
Even when the texture of a substance is not actually changed by adding or taking heat from it, certain variations of heat will alter its dimensions, a principle well known to country artisans, who, in order that the iron hoop of a cart wheel may fit tight, make it, at first, a little smaller than the wheel; then they heat it strongly by a fire of brush wood, and when it is thus considerably widening by the addition of heat, they apply it to the wheel, and as it cools it contracts tightly around the wheel.

Discovery of the Condensation of Gases.

It has been customary to divide substances having the texture of air or steam, into gases and vapours; though the distinction was by no means good, depending as it did merely on gases not being condensible by abstracting their heat, as vapours are. The ingenious experiments of Mr. Faraday, in 1823, by which he succeeded in condensing a number of the gases formerly held to be incondensible, clearly showed the inaccuracy of the classification.

It had long been known, that in rendering any substance more compact in texture by hammering or pressure, it gives out heat, that is, its insensible heat is forced out and becomes sensible. Thus a piece of iron may be hammered till it becomes red hot, and if a quantity of air be suddenly compressed, as by the piston of a syringe, or in the ball of an air gun, it will give out enough of heat to set fire to tinder or gunpowder. It was a fair inference from this, that if sufficient pressure were applied to the gases, their heat might be forced out sufficiently to change their texture to that of liquids or solids.

Mr. Faraday's contrivance, while it went upon this principle, embraced another, by providing for the quick removal of the heat forced out from the gas by pressure, which otherwise might have tended to obstruct the abstraction of the rest. The contrivance may be exemplified in the instance of carbonic acid as, by bending a very strong glass tube six inches long into an angle two inches from the end, which is then closed by melting the glass [1]. The bent part of the glass is then nearly filled with very strong sulphuric acid, taking care not to wet the part above, which is nearly filled with small bits of the compound of carbonic acid and ammonia [2], but so as not to touch the acid below it, till the upper end of the tube has been closed in the same way as the under, when the acid is made to run into the longer part of the tube. The ammonia in that case joins with the sulphuric acid, and sets free the carbonic acid gas, which being



Mr. Faraday's experiment for liquefying carbonic acid gas :—*a*, the lower bent end of the tube, containing strong sulphuric acid; *b*, the bits of the compound of carbonic acid gas and ammonia (2); *c*, a vessel with pounded ice.

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(1) Technically, *Hermetically sealed*, from the name of *Hermes*, an Egyptian philosopher, who is said to have lived more than three thousand years ago.

(2) Technically, *Carbonate of Ammonia*.

prevented from escape or expansion by the closed gas, heavy pressure is produced by its acting on itself; and as heat is thus forced out, it is carried off by plunging the longer end of the tube into snow, or pounded ice. The carbonic acid gas by this management has its gaseous texture changed into a liquid one, appearing limpid and colourless.

Other gases, to the number of nine or ten, have been liquefied in a similar manner; but hitherto the important gases, oxygen, hydrogen, and nitrogen, have proved refractory, though it is highly probable these may ultimately be condensed, as our means of operating become improved.

We are, from these experiments, "led to regard it," in the words of Sir John Herschel, "as a general fact, that the liquid and aëriform, or vaporous states, are entirely dependent on heat; that were it not for this cause there would be nothing but solids in nature; and that, on the other hand, nothing but a sufficient intensity of heat is requisite to destroy the cohesion of every substance, and reduce all bodies, first to liquids, and then to vapour."

Explanation of Burning[1] *and Flame.*

When oxygen was first discovered, it was supposed to be the sole and exclusive agent in the process of

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(1) Technically, *Combustion*; from the Latin, *cum*, "toge[illegible]r," and *bustum*, "burnt," the latter from the Greek πυρ, [illegible]."

burning, and there can be no doubt of its being very universally present in such cases; but recent discovery has shown that it is inaccurate to make it the exclusive agent, for burning is nothing more than the forcing out by chemical combination a quantity of insensible heat, so as to render it sensible. As every substance, therefore, even ice and snow, contains more or less insensible heat, whatever circumstances may force out enough of this insensible heat, to render its effects visible by producing fire or flame, will cause burning, whether oxygen be present or not.

In the case of oxygen, if a small bit of the new metal potassium be placed on ice or snow, it will combine with the oxygen therein contained, and at the same time force out its heat in form of a very brilliant flame, proving that the ice or the snow contains a great deal of heat. In the instance of burning wood, or coal, the heat evolved is forced out from the oxygen in the air around the fire, and when more air is blown into the fire by means of a pair of bellows, the heat is increased, because the quantity of oxygen is increased. The oxygen in all these cases becomes solid as it gives out its heat, as is proved by burnt substances, when none of their materials are diffused in vapour, becoming heavier than before burning. Solid oxygen, however, has not hitherto been obtained apart from the substances with which it combines.

One of the most remarkable instances of these observations, is the burning of the diamond, the hardest of all known substances. The process is effected

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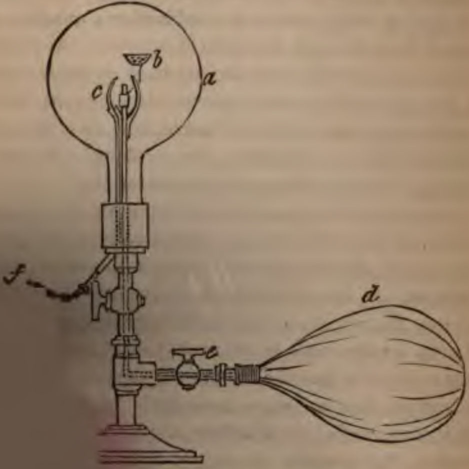
by burning the diamond in oxygen gas, through the agency of electricity and hydrogen gas, the apparatus for which is here figured.



[illegible] of burning the diamond in oxygen gas :—*a*, a
[illegible] led, after its exhaustion of air, with 140 cubic
[illegible] gen gas; *b*, a platinum cup pierced with small
[illegible] aining the diamonds to be burned; *c*, a small tube
[illegible] rs of an inch below the cup, through which a jet
[illegible] gas is emitted from the bladder *d*, by the communi-
[illegible] *e*. The jet of hydrogen is set fire to by an electrical
[illegible] ough the chain *f*, communicating with the wires that
[illegible] *c*.

[illegible] hen the stream of lighted hydrogen gas has
[illegible] ught the diamonds in the cup to a white heat,
[illegible] cut off, and the whole allowed to cool, when, in-

stead of oxygen gas in the globe, there is found carbonic acid gas, of the same bulk indeed as the oxygen, which had disappeared, but with an addition of weight precisely equal to the weight of diamond consumed, proving it to be pure carbon.

The other simple substances, whose rapid combination in forming compound substances, forces out so much of their previously insensible heat, as to render it visible in fire or flame, are chlorine, bromine, and iodine; but these are so seldom met with, except by chemists, that in all common instances of fire, Lavoisier's oxygen theory still holds good; and as an important inference therefrom, it may be stated, that all burning consumes the oxygen of the air, and of course deteriorates it in quality.

Unless heat and light be identical, (as is now partially held,) or associated very constantly together, it will not be easy to explain the luminous appearances exhibited in the preceding cases. Flame, however, is much better understood, in consequence of the researches of Sir H. Davy, and I may also say of my lamented friend, George Oswald Sym, M. A., by whose early death science lost a zealous and accurate votary.

Flame does not appear to me to be correctly described by Dr. Lardner, as "gas heated to whiteness (1)," nor by Dr. Turner as "gaseous matter, heated so intensely, as to be luminous (2)." M. Babinet comes nearer the facts, when he calls it the "incandescence," that is, the white heat, "of combining gases." For it is not surely the oxygen in the flame of a candle which is heated to whiteness, nor the hydrogen and carbon, nor these mixed or combined with oxygen; but it is the heat previously insensible in one or all of these, which is forced out and becomes luminous, either as an inherent quality of a certain quantity of heat, or as associated when in such quantity with light. It might as well be said, that the full light of the sun is gas heated to whiteness, as thus to describe the flame of a candle. The heat from the burning wick of a candle, decomposes the tallow or the wax, and causes the hydrogen and carbon therein contained to rise in a circle round the wick, in form of hot vapour, which, combining with the oxygen of the air, forces out its insensible heat in such quantity as becomes luminous a little below the tip of the wick. This forced-out heat again acts on the rising circle of vapour, and expands it so, that it is wider about the level of the tip of the wick than below this. The surrounding air also carries off the evolved heat more rapidly, and in proportion as the circle of vapour rises, this becomes gradually narrower, till it ends in a point.

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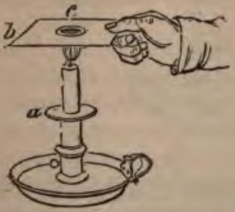
(1) Treatise on Heat, p. 358.

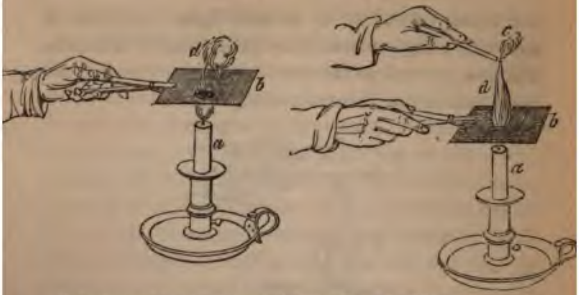
(2) Chemistry, p. 349, 3rd edition.

Mr. G. O. Sym, if I am not much mistaken, was the first to prove that flame is hollow, that is, there is only a thin portion, like a coiled leaf of paper, which is luminous, because there is not a sufficient supply of oxygen in the central part to combine with the rising vapour so as to emit light. A piece of wire accordingly placed across the flame of a candle, will become red at the outsides of the flame, while within these it will remain black.



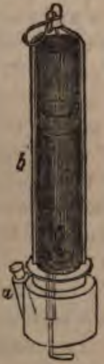
Dissection of the flame of a candle, *a*, by a piece of glass, *b*, held over it, to show that it is hollow, *c*.

A beautiful and importantly useful application of the doctrine of flame was made by Sir H Davy in the case of the instrument called the *Safety Lamp*. We have seen above, that a tin saucepan can be kept from melting by means of water carrying off the accumulating heat; and on the same principle, one half or two thirds of the flame of a lamp or candle can be extinguished by carrying off its heat, which may be proved by placing over a flame a bit of wire gauze, the wire in the gauze laying hold of so much of the heat forced out by the combination of the gases that no flame will thus pass through the meshes; and, consequently, a lamp surrounded with wire gauze may be carried in safety amidst hydrogen gas, which would, without this precaution, explode more violently than gunpowder.



Experiments on the flame of a candle, *a*, with a bit of wire gauze, *b*; on the left the smoke, *d*, is not inflamed, but on the right *d*, is lighted by a taper *c*.

Now, in coal mines, great quantities of this explosive hydrogen are sometimes collected, partially mingled of course with the common air, and when open



Sir H. Davy's Safety Lamp :—*a*, the lamp with a bent wire for cleaning it; *b*, the wire gauze cage.

lamps have been carried into it, dreadful explosions have occurred, and many lives have thus been lost. This Sir H. Davy's wire gauze lamp effectually prevents, and even, by the enlargement of the flame within, gives the miners timely warning of the danger.

Source of Heat in Animals and in Plants.

The source of heat in animals and plants has given rise to much discussion and differences of opinion, which I cannot spare room to go into here[1]; but shall state what appears to be chemically true, whatever other sources of heat there may be.

The animal blood, containing a quantity of carbon, is brought from all parts of the body by the veins, and carried to the heart, by whose motion or beating it is thrown into a large vein[2], and carried to the lungs, where it is distributed into innumerable small tubes, and exposed through their very thin membranes to the fresh air taken in by breathing. Here the blood, which is now dark coloured, takes from the air a part of its oxygen, with which it combines, rendering the dark blood bright scarlet, while at the same time another portion of the oxygen unites with the carbon and hydrogen of the blood, and passes off into the air by the returning breath. In both of these combinations the insensible heat of the oxygen must be forced out, and of course must be communicated to the bright red and pure blood which is returned to the heart,

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(1) Details will be given in the "ALPHABET OF PHYSIOLOGY."

(2) Technically, the *Pulmonary vein.*

and thrown by it into the arteries to be distributed to all parts of the body, in order to supply heat as well as fresh materials for the growth and repair of the several parts. A man absorbs about two pounds and a half of oxygen in twenty-four hours.

Such is the account first given by Dr. Crawford, and in part confirmed by the recent experiments of Dr. Edwards, of Paris, who has proved "that the oxygen of the air taken into the lungs by breathing, is wholly absorbed, being carried into the circulating blood; that it is replaced by a quantity more or less equivalent of carbonic acid exhaled in whole or in part from that which is contained in the venous or dark-coloured blood; that the animal besides absorbs from the air a portion of its nitrogen, which is carried in whole, or in part, into the mass of the blood; and that the nitrogen absorbed is replaced by a quantity more or less equivalent of nitrogen exhaled in whole or in part from the blood."

According to the experiments of Jurine and Abernethy, a somewhat similar process goes on over the whole surface of the skin; and if this be correct, it will account for the production of all the heat in an animal body.

It is a very striking fact, that the heat of animals is very nearly the same in all climates, in the burning deserts of Africa, and in the frozen regions near the Pole; but this follows clearly from the preceding explanation; for so long as the lungs can act in absorbing oxygen, it will give out the same quantity of heat. When the heart is made to beat rapidly by muscular exertion, or other means, more air is taken in by breathing, and more oxygen is of course consumed, as in blowing a fire, and more heat given out.

To the uninstructed, however, it appears no less erroneous to say, that the body is equally warm on a cold winter's morning, and on the most sultry of the dog days, as to affirm that the sun is stationary, contrary to the apparent evidence of the senses; yet the one truth is as well ascertained as the other. For example, Captain Parry found, that when the air was from three degrees above zero, up to the freezing point, at Winter Isle, lat. 66° 11′ N., the interior temperature of the foxes when killed, was from 106¾ degrees to 98 degrees; and at Ceylon, Dr. John Davy found that the temperature of the native inhabitants differed only about one or two degrees from the ordinary standard in England. At very high temperatures, however, there is a little more difference, as appears from the ingenious experiments of Delaroche and Berger, who exposed themselves to a heat of 228 degrees, that is 16 degrees above the boiling point of water, and ascertained that in such cases there is a considerable increase of heat, as might indeed have been anticipated from the principles I have here laid down.

It is worth remarking, that the process above described as taking place in the lungs, is performed without the presence of light, a circumstance usually overlooked; and in the dark, the very same process is performed on the surface of the leaves of plants, where the sap, like the venous, or dark-coloured blood in the lungs, is exposed to the fresh air, from which it takes oxygen and gives carbonic acid gas in return. In the light of the sun, or in bright artificial light in greenhouses, this process is reversed, the leaves giving out oxygen to the air, and absorbing carbonic acid; consequently air, which has been robbed of its oxygen by fires, by the breathing of animals, or by the vegetation of plants in the night, has this oxygen restored by the vegetation of plants by day. Even in winter, accordingly, plants are warmer than the surrounding air, as may be proved by boring into a tree, and inserting a thermometer in the hole, when it will be seen to rise.

Sensible and Unconfined or Free Heat.

The heat which passes readily from one substance to another, either in consequence of some chemical combination causing its emission, or when no such combination is going forward, and which is not fixed, as in the preceding case, may be called sensible heat. The most remarkable circumstances with respect to sensible heat, is the mode in which it passes from one contiguous substance to another, termed *Radiation*[1]; and in which, on the other hand, it passes through the

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(1) From the Latin, *Radius*, "a ray," or "the spoke of a wheel."

parts of an individual substance or several substances, touching each other, termed *conduction*[1].

RADIATION.—Whenever sensible heat is given out, it streams off all around in straight lines or rays, which will pass through air or gas in the same way as rays of light will, till they meet with some substance capable of stopping them, or of reflecting them, as light is reflected from a looking-glass. It would appear, indeed, from the researches of M. Prevost of Geneva, that streams of heat are at all times passing off from every substance, but more from those which are hotter towards those near them, which are colder, till an equal diffusion of heat is produced among them, so that when a fire sends off heat to a bit of ice, the ice in turn sends off some to the fire, in the same way as when the sun sends light to a burning candle, the candle in turn sends back some light towards the sun.

M. Pictet, of Geneva, on the other hand, denies this mutual radiation, and maintains that radiation ceases when a cold body takes the same degree of heat as a hot one near it.

In order to prove the radiation of heat, M. Pictet contrived a very ingenious experiment, by means of concave mirrors, the peculiar form of which causes the rays of heat, reflected from them, to meet in a point[2] in form of the mirror.

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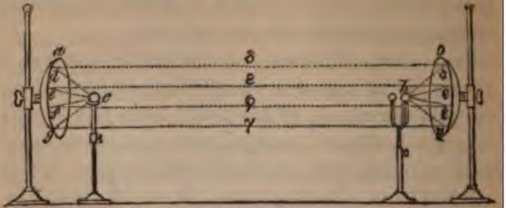
(1) From the Latin, *Cum*, "with," and *Ductio*, "leading," or "guiding."

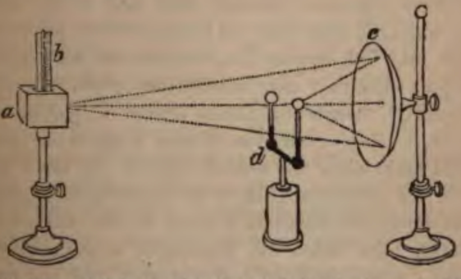
(2) Technically, *Focus*, which is Latin for "a fire-place."



Professor Pictet's experiment on the radiation of heat:—*a*, *b*, two large block-tin mirrors, parabolically concave, and placed opposite each other, about ten feet apart; *c*, a ball of iron, about two inches diameter, made as hot as possible, not to be red or luminous, and placed in the focus of the mirror; *d*, *e*, *f*, *g*, rays of heat from the ball to the mirror, *a*, and reflected in the lines δ, ϵ, φ, γ, which are again reflected from the mirror, *b*, in the lines 𝔡, 𝔢, 𝔣, 𝔤, converging to the focus, in which is placed the bulb, *h*, of a differential thermometer.

The effect of reflecting the rays of heat to a point in this manner, is to expand the air in the bulb of the thermometer, and, of course, to cause it to press on the fluid in the tube, which will rise in the opposite tube. If a piece of ice be placed at *c* instead of the hot iron, the bulb of the thermometer being now the hotter of the two, sends off so many more rays of heat than it receives, that the air in it is condensed, and the fluid in the opposite tube, sustaining less pressure, rises. In any other intermediate point than the focus of the two mirrors, the effect of the rays of heat is much less, in consequence of their not being brought to a point.

Professor Leslie extended, in a very ingenious manner, the researches of Saussure, Pictet, and Prevost, by filling a square tin box with hot water, and bringing the rays of heat emitted from it, into a focus, by a concave mirror, similar to the preceding. He arrived by this means at the remarkable and interesting conclusion, that the rays of heat stream off in greater number from a rough, dull surface, than from a smooth and bright one; for by covering the surface of the tin with a thin coating of isinglass, paper, lamp-black, writing-wax, or resin, the radiation of heat was greatly increased, as it was also by scratching or rubbing off the polish of the tin. It follows that the brighter a silver tea-pot or a roasting-screen is kept, the longer will the heat be retained, and thus pipes for warming houses, or plant-stoves, ought not to be polished. Black also radiates more than white.



Sir John Leslie's experiment on radiating heat:—*a*, tin box, containing hot water, whose sides were successively covered with various substances; *b*, thermometer, to show the heat of the water; *c*, parabolic concave mirror of polished metal; *d*, differential thermometer, with one of its bulbs in the focus of the mirror.

The same ingenious experimenter further proved that a surface that radiates heat well, reflects heat badly, and the contrary; bright polished metals, for instance, which radiate so slightly, reflect much of the heat that comes to them from without. This may be familiarly proved by standing at the side of a fire, so as that the heat from it may not fall directly on the face, while a broad piece of polished metal is placed opposite the grate, so as to permit the observer to see in it the reflection of the fire, when a glow of heat will be instantly felt on the face. If a piece of cloth, wood, or any other imperfectly reflecting substance, be substituted for the metal, no glow will be felt[1].

CONDUCTION.—When a piece of iron or glass are brought to the same degree of heat, they feel of very different degrees of warmth, when held in the hand, for while the glass may feel but moderately warm, the iron may feel burning hot, because iron allows heat to pass through it more readily than glass, and, consequently, though at the same degree of heat as the glass, it will give out more of what it has to the hand. Iron again when not heated, will, for the same reason, feel colder than glass at an equal degree of heat; and among the things in a room, as Dr. Turner remarks, "the carpet will feel nearly as warm as the hand; a book will feel cool, the table cold, the mar-

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(1) Other important illustrations of radiant and reflected heat are given in "ALPHABET OF SCIENTIFIC GARDENING," page 20.

ble chimney-piece colder, and the candle-stick colder still; yet, a thermometer applied to them will stand exactly at the same height." They are all really colder than the hand; but those that carry away heat most rapidly, produce the strongest feeling of cold.

M. Despretz made experiments on the conducting power of various substances by applying the heat of a lamp to the end of a bar of the substance, coated with varnish, while a thermometer was placed at the other end. The results were as follows.

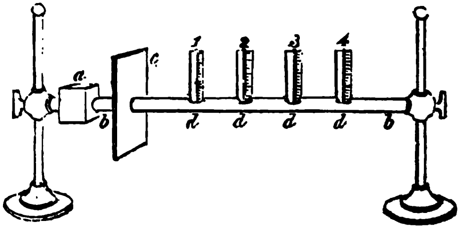
	Conductive Power.
Gold	100
Platinum	98.1
Silver	97.3
Copper	89.82
Iron	37.41
Zinc	36.37
Tin	30.38
Lead	17.96
Marble	2.34
Porcelain	1.22
Brick earth	1.13

Count Rumford tried some ingenious experiments on the materials of dress, in order to ascertain their conducting powers, by placing a thermometer in a glass cylinder, and filling the vacant space with what was to be examined. He then first plunged the whole into boiling water to bring it to 212 degrees, and transferring it into pounded ice, he noted the time which elapsed before the thermometer fell to the freezing point of 32 degrees. By this means he found that

		Seconds.
There elapsed to cool down	Atmospheric air	576
	Fine lint	1032
	Cotton wool	1046
	Sheep's wool	1118
	Raw silk	1284
	Beavers' fur	1296
	Eider down	1305
	Hares' fur	1815

Consequently hares' fur is by far the warmest, and lint the coldest of all these articles of clothing; for the warmth effected by clothing is not in consequence of any heat in the dress, but in consequence of its preventing the escape of the animal heat from the body.

Dr. Lardner, in his excellent Treatise on Heat, explains the process of conduction by the following very ingenious instrument:—



Dr. Lardner's experiment on the conduction of heat:—*a*, a square block of red-hot iron, in contact with *b*, one end of a bar of brass, which passes through a screen, *c*, to intercept the heat which radiates from the iron; *d*, *d*, *d*, *d*, small cavities in the brass bar, filled with quick-silver, into which are plunged the bulbs of the thermometers, 1, 2, 3, 4.

Before the red-hot iron is made to touch the brass bar, all the thermometers will stand at the same degree, but soon after it is made to touch, the first thermometer will rise slowly, and successively all the others as the heat is conducted along the bar.

LIGHT might require a notice in this place similar to heat; but as its chemical effects are but very partially and imperfectly ascertained, I shall postpone their consideration till another opportunity[1].

EFFECTS OF ELECTRICITY ON TEXTURE.

THE same fanciful views with respect to substance, *essence*, or *matter*, have been taken of the agent termed *Electricity*[2], similar in many respects to heat, as I have above pointed out; and in books we accordingly often meet with the term *electric fluid*, though nothing in the least resembling a fluid has ever been traced as the agent in electrical phenomena, and the writers, indeed, in the same breath, impertinently tell us that "its *nature* is unknown."

In the account already given of the discovery of the composition of water, and in several other

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(1) Details will be given in the "ALPHABET OF LIGHT AND COLOURS." See also "ALPHABET OF SCIENTIFIC GARDENING, page 17.

(2) From the Greek, ῾ηλεκτρον, "amber."

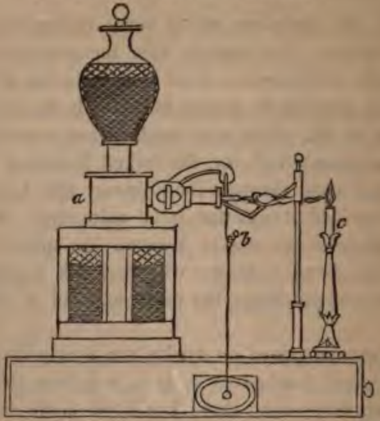
instances, the power of electrical agency in producing chemical combination, as well as in dissevering the constituents of a compound, have been incidentally illustrated.

Like heat, electricity varies much in its rapidity of passage through different substances; but heat appears to pass more or less rapidly through all, whereas electricity, as was discovered by Mr. Grey, in 1729, and proved by M. Dufay, in 1733, while it passes freely along certain substances, is arrested, more or less entirely, by others. The first are termed *conductors*, among which are all metals, charcoal, water, and plants and animals, because they contain water; the last are termed *non-conductors;* among which are glass, resins, sulphur, diamond, dried wood, dry silk, hair, wool, and atmospheric air, when not damp.

It is the property of damp air, indeed, in carrying off the due portion of electricity from the body, without which we can never enjoy health nor comfort, that renders damp, foggy weather proverbially gloomy and cheerless. When this portion is deficient, we feel languid, heavy, and low-spirited, and we very foolishly pronounce a libel on the blood, which is quite innocent, while we never suspect the damp atmosphere of robbing us of our electricity. Yet so it is. In dry weather, whether it be warm, cold or frosty, we feel light and spirited; because dry air is a slow conductor of electricity, and leaves us to enjoy its luxuries. In moist or rainy weather, we feel oppressed and drowsy; because all moisture greedily absorbs our electricity, which is the buoyant cordial of the body. To remedy this inconvenience, we have only to discover a good non-conductor of electricity to prevent its escape from the body, and this we have in silk, which is so excellent a non-conductor, that the thunderbolt, or the forked lightning itself, could not pass through the thinnest silk handkerchief, provided always that it be quite dry. Those, therefore, who are apt to become low-spirited and listless in damp weather, will find silk waistcoats, drawers, and stockings, the most powerful of all cordials.

The conductors of electricity are nearly the same as the good conductors of heat, and from this and other circumstances, there has been made out between them a close similarity, if not an identity. If an excited conductor, such as a metallic wire, be made to communicate at one of its extremities with the earth, the electricity will pass to it from the opposite end in an instant, even though it were several miles in length; so that where the balance is disturbed, it will at once be restored along the whole wire, just as effectually as if every point of it communicated with the ground.

When electricity is accumulated and condensed, the discharge, as it is termed, is accompanied by a bright fiery spark, which will communicate flame to hydrogen gas, and other combustible materials, as we have already seen. This is turned to advantage in the construction of the following elegant apparatus for *producing instantaneous* light.



Apparatus for instantaneous light :—*a*, a gas holder, containng combustible gas; *b*, an electrical conductor for setting fire o the jet of gas; *d*, a candle lighted by the jet.

The apparatus invented by Galvani, Volta, and Cruickshank, for evolving concentrated electricity through the agency of the chemical action of certain substances on each other, renders the preceding view of its similarity to heat highly probable. The recent researches of M. Pouillet and others on this interesting subject, will come under notice in another place(1).

EFFECTS OF POLARITY ON TEXTURE.

THE well-known property of the magnetic needle of the mariners' compass to stand with one end directed towards the north pole, and the other towards the south pole, is termed its *polarity*; and recent researches lead to the conclusion that the particles of all substances may be more or less affected with some species of similar polarity, not perhaps directed north and south, like the compass needle, but in some other direction, so as to influence the conformity of arrangement in the combinations of chemical substances. It is proved by the most rigid experiment, that both the rays of light and heat possess polarity, a discovery first made by M. Malus, and since investigated by Arago, Fresnel, Biot, and Brewster. Professor Oerstedt, of Copenhagen, discovered that electricity gave polarity; and it was discovered by Dr. Morichini of Rome, and since proved by Mrs. Somerville, that certain rays of light impart magnetic polarity to iron and steel. Berzelius indeed announces generally, that in all bodies "the particles, or atoms, are endowed with a certain polarity, and with a different intensity of action in the poles of those atoms."

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(1) The several "ALPHABETS OF ELECTRICITY, OF GALVAN-, AND OF METEOROLOGY," will afford room for details.

On looking at a number of substances in this point of view, we find that some are very regular in texture, while others are irregular[1], the regular being said to be crystallised[2], the irregular not crystallised. It will

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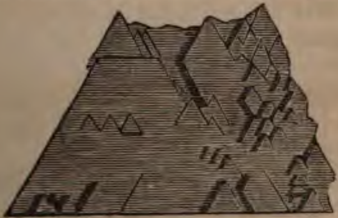
(1) Technically, *Amorphous*, from the Greek α, "without," and μορφη, "form."

(2) Crystal, from the Greek κρυϛαλλος, "ice," or "glass."

be useful here to notice briefly the subject of crystallisation.

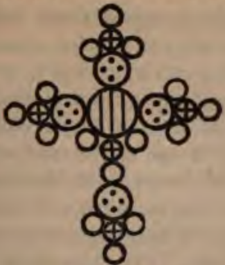
Structure and Formation of Crystals.

The term "crystal" is not confined to substance transparent, like ice or glass, which was the origin meaning of the term, but is now applied to all substances which take a regular form in consequence chemical change. The celebrated Bergman appear to have been the first who thought of dissecting crystals in order to ascertain their structure; but he confined himself to mechanical dissections. Profess Daniell contrived the still more ingenious method dissecting crystals, by dissolving them in a solven and Mr. Faraday has extended his experiments.

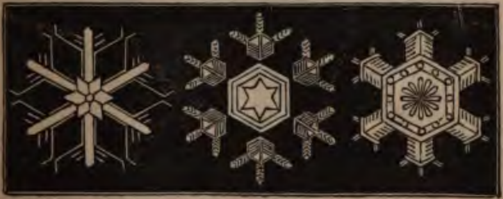


Mr. Daniell's dissection of crystals:—a mass of alum, which h been immersed in water till the crystals appear on the surface

Mr. Dalton has represented a crystal of alum according to his notion of the globular form of th several particles, in the following manner:—

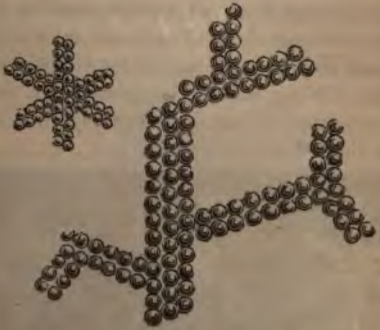


One of the most familiar instances of crystallisation occurs in water, as when we see it shoot out into needle-like lines on the edge of a pond, and in the bristling of hoar frost, or arrange itself in every diversity of elegant form when frozen upon window glass; and no less so, though seldomer observed, in the flakes of falling snow, as is represented in the following magnified figures from Scoresby's interesting work on the " Arctic Regions."



Flakes of snow magnified to show the variety in the arrangement of their crystals.

This common instance, illustrative of polarity, accounts in the clearest manner for a circumstance that seems to contradict the general position of heat causing substances to expand; and cold, that is, the absence of heat, being productive of contraction. So great is the force with which water, in consequence of polarity, expands upon freezing, that it has been made, in the experiments of Major Williams, to burst iron bombs, and is one of the most active agents in rending mountain rocks[1]. M. de Mairan was the first to ascertain that the crystals of ice are constantly joined at an angle of sixty degrees, or of one hundred and twenty degrees. The interstices produced by this arrangement render ice from a tenth to a twelfth lighter than water.



Arrangement, according to Dalton, of the drops of water in the branching ice formed on window glass, to show the angles f 60° and 120° when formed.

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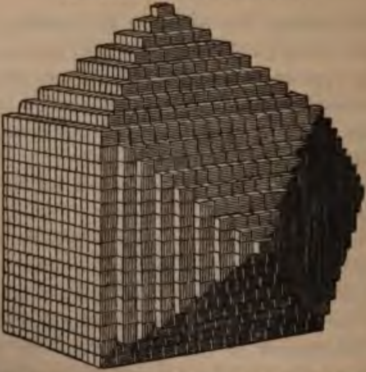
[1] Details will be given in the "ALPHABET of GEOLOGY." ALPHABET OF SCIENTIFIC GARDENING," page 59.

Within certain interstices in all crystals, either formed in this way, or from some other cause, a small portion of water is always lodged, termed the water of crystallisation, which may in general be expelled by means of heat; but in that case the form of the crystal is destroyed, as may be shown by heating crystals of Epsom salts, so as to drive off the water of crystallisation.

It would appear most probable, from the experiments of Professor Daniell, that the particles of which crystals are composed, are of a globular form, accounting for the smooth surface of crystals from the extreme minuteness of the particles. The regular arrangement of such globular particles may be represented by bullets piled up into regular figures, as represented in the engraving.

A pyramid of globules to show the supposed structure of pyramidal crystals.

It was supposed by Romé de l'Isle, Haüy, and Möhs, that the form of crystals affords a good characteristic for distinguishing minerals; but though this appeared very plausible, and was adopted by Jameson and *others, it has* been overturned by the discoveries



Supposed structure of crystals:—a twelve-sided[1] crystal, supposed to be magnified and formed of minute cubes, which may again be supposed to be formed of globules. The faces are formed by a line of cubes being removed.

of Professor Mitscherlich, of Berlin, in 1819. He found that a number of substances produce salts, having their crystals of the same form[2], phosphorus and arsenic acids being the first of these observed, whose salts have the same formed crystals; and since then he has discovered, amongst other instances, that the same holds true of the salts formed by the selenic and sulphuric acids; by lime and magnesia; and by iron, cobalt, and nickel. It is worthy of remark, as tending to prove what I have said above, that Mitscherlich finds, in crystals of the same form, the water of crystallisation is the same in quantity.

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(1) Technically, *Dodecahedron*, from the Greek.

(2) Technically, *Isomorphous*, from the Greek, ἴσος, "same," and *μορφη*, "form."

LAWS OF CHEMICAL COMBINATIONS.

WHEN we say that water, by running down a slope, or a stone by falling from a height, obeys the LAW of attraction; or that needles of ice, shooting in multitudinous branches over a pane of glass, obey the LAW of polarity, we do not thereby suppose the stone or the ice to possess a will, or that they have the power to break or disobey the law; but simply that they so act, when certain laws compel their obedience; and consequently the term LAW refers in these cases more to the observer than to the phenomena observed,—an imperfection of language such as often occurs in science, but which can seldom be remedied. What I here term laws, then, are merely generalisations of facts, derived from experiments, and inductions therefrom, some of which are of great importance, and will require the careful study of the beginner. I shall consider them under the two heads of Preference and Proportion.

LAWS OF CHEMICAL PREFERENCE.

IT is an irresistible propensity in the human mind to ascribe life and even thinking, to things which neither live nor think[1]. This has been carried even into the highest branches of science, and we cannot well explain the chemical laws, under consideration, without supposing all chemical substances to have their peculiar likings and dislikings for each other, so as to determine them to associate, or to separate. The beginner, however, must not suppose that in using such figurative terms, we really mean that iron, water, or air can possess likings or dislikings similar to our own. We employ the terms, because we cannot find others so clearly expressive of the facts.

Some chemical substances, then, show a very marked preference of each other, and no less a marked antipathy to some other substances, as much as a brood of chickens will keep close to their mother and will scuttle away for fear of a kite. The chemical preferences in question are observable between substances the same or similar, and between substances that are dissimilar, each of which I shall now consider.

Preferences between Substances the same or similar.

It is in consequence of what I have termed the preference between the same substances[2] that a piece of iron can be drawn out into wire, and that gold can be beat into leaves thinner than tissue paper, and

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(1) This will be discussed in the "ALPHABET OF MODERN PHILOSOPHY."

(1) Technically, *Cohesion*, or *Attraction of Cohesion*, from the Latin, *Cohærere*, "to stick together."

that quicksilver poured upon a table will run into little globules, like dew drops, without any separation of their particles, which *prefer* to remain united, and strongly resist being separated. In some substances, the particles have a stronger preference than in others, and upon this, together with the arrangement of these particles, arising from their polarity, the important quality of strength in the materials used for building and other purposes, wholly depends ; a subject first investigated scientifically by Muschenbroek. It was proved, for instance, by Emerson, that an iron rod an inch square will bear a weight of 76,400 pounds, while a square inch of lead will only bear 430 pounds ; Captain Brown again found that 16,265 pounds will tear asunder an inch square of cast iron ; and Mr. Barlow, that a square inch of box wood will bear about 20,000 pounds' weight, while a square inch of mahogany will only bear 8,000 pounds.[1]

Sir Gilbert Blane found that the muscle which bends the thumb, taken from a man five hours after death, and before it was stiff or quite cold, bore 26 pounds before it gave way ; in the living subject it would in some cases bear the double of this.

The great opponent to this union of substances from preference is heat ; for by insinuating itself between the particles, it pushes them asunder ; and when increased, as we have already seen, to a certain

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(1) This will be farther detailed in the "ALPHABET OF SCIENTIFIC ENGINEERING."

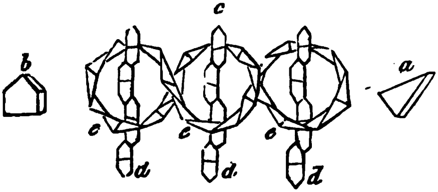
degree, it will, in a great measure, disjoin them. Mechanical means, however, are most usually had recourse to, when it is requisite to separate particles thus united by preference, and hence the chemist uses the hammer, the file, the pestle and mortar, and other similar contrivances.

When the particles of substances have been disjoined by heat, they may, in some cases, be joined again by taking away the heat, as in the instance of steam condensed into water. When the disjunction has been made by mechanical means, it is difficult to reunite them, not from their losing the power of preference,—this never happens,—but from its not being easy to bring the preference into play, in consequence of the opposition from heat. If this can be overcome and the surfaces be brought sufficiently near, the preference will operate almost as strongly as before the disjunction. In this way, two leaden bullets, having each a flat surface of a quarter of an inch across, if scraped very smooth, will, upon being strongly pressed together, exhibit a preference, that is, they will [illegible] with a force, which will sometimes [illegible] of a hundred pounds' weight to over[illegible] if two drops of quicksilver be placed [illegible], and pushed gently till they mutually [illegible] will unite into one drop; but, if previously [illegible] they will not unite, because the film of [illegible] opposes the operation of their preference, as [illegible] in almost every instance.

Preferences between dissimilar Substances.

The particles of one substance frequently show a marked preference in associating or combining with the particles of a different substance, a circumstance which produces many results of great interest. I have already stated that an alkali will turn a vegetable blue colour to green, and an acid will turn it red; but when an alkali and an acid, having a mutual preference,[1] combine and form a salt, this salt will not change the blue colour either to red or green, and will not taste either acid or alkaline.

It was the opinion of the older chemists that the particles of acids and alkalies were of different form, though each were held to have sharp points, which, by insinuating themselves into interstices, formed the compound substance, that from this arrangement of the points did not taste acid or alkaline.



Representation of the supposed figures of particles:—*a*, particle of acid; *b*, particle of alkali; *c*, these combined in a salt; *d*, *d*, *d*, the union of the particles of alkali in upright lines; *e*, *e*, *e*, the union of the particles of acid in circles.

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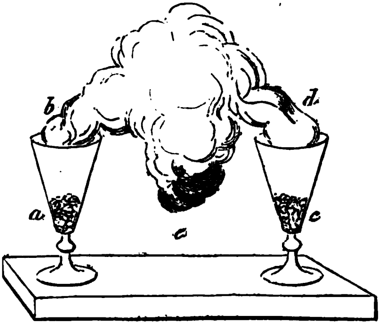
[1] Technically, *Affinity* or *Elective* attraction.

This notion, however, is altogether fanciful, and might be disproved, if it were worth the trouble, by many circumstances. It will be more advantageous to illustrate ascertained facts.

The preference between dissimilar particles can only be shown when they are minutely divided, and seldom unless one or both substances be fluid or gaseous. An instance of two dry substances combining, occurs in taking some sugar of lead[1] and some zinc combined with sulphuric acid[2] both in fine powder, which being rubbed together in a mortar, will form a fluid. An instance of the combination of gaseous substances occurs in mixing the gas of ammonia with hydrochloric acid gas[3]. This is easily done by putting



Experiment of two gases forming a solid;—*a*, glass with sal ammoniac and quick lime; *b*, the ammoniacal gas disengaged; *c*, glass with sal ammoniac and sulphuric acid; *d*, the hydrochloric acid gas; *e*, dense fumes of sal ammoniac formed.

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(1) Technically, Acetate of lead.

(2) Technically, Sulphate of zinc.

(3) Formerly, Muriatic acid gas.

some sal ammoniac into two wine glasses, and into one put a little quick lime, and into the other sulphuric acid, when the lime will disengage the ammonia, and the sulphuric acid will disengage the hydrochloric acid gas. Now bring the glasses so that the two gases may intermingle, when thick white fumes will form and fall down in form of sal ammoniac.

The compound substance resulting from the union of two dissimilar substances, is, as I have already shown in numerous instances, totally different from either of the constituents. If we add, for instance, to common hartshorn, which is water containing ammonia, and of a very pungent odour, a quantity of concentrated hydrochloric acid, which is also of very pungent smell, the sal ammoniac thus produced will have no smell. If again we dissolve a little of the compound of potass and hydrocyanic acid[1] in a glass of water, and add to it some copperas dissolved in water, though both these fluids are without colour, they will, on uniting, produce the bright deep blue called Prussian blue. By adding some infusion of galls to the solution of the copperas[2], though both are nearly colourless, a deep black will be produced, which is common writing-ink.

The most striking law, however, of chemical preference in dissimilar substances occurs in cases where two or more substances leave such as they have been

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(1) Technically, *Hydrocyanate of potass*, formerly, *Prussiate of potass.*

(2) Technically, *Sulphate of iron.*

previously combined with, in order to unite wit others, showing that our term preference is somethin nearer the fact than a mere figurative expression This may be well shown by pouring some nitric aci upon a bit of copper, such as a clean penny piece, i a glass, when the acid will combine with the coppe in form of a fine blue liquid. The acid, howeve prefers uniting with iron rather than with copper, an if a bright knife be dipped into the liquid, part of th acid will combine with the iron, leaving the coppe on the surface of the knife, which will appear to b no longer iron, but copper.

Bergmann was amongst the first to give the pre ceding explanation ; but it is not by any mea strictly accurate, for so many circumstances are to b taken into account, that it would be wrong to asse generally, that of three substances, as in the precedin example, two show a preference of combining, to t exclusion of the third. For example, when a strea of hydrogen gas is passed over the compound of iro and oxygen,[1] heated to redness, the oxygen leaves t iron to combine with the hydrogen, and forms wate but if this water is converted into vapour, and aga passed over the red-hot metallic iron, now deprive of oxygen, the oxygen leaves the water and combin with the iron. Notwithstanding this, however, it found, in practice, to answer very well, in most case to trust to certain tables originally drawn up b

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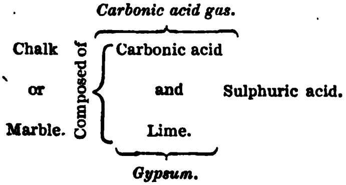
(1) Technically, Oxide of iron.

Bergmann and Geoffroy, exhibiting the preferences of a great number of substances, and upon this principle indeed is founded the whole doctrine and practice of tests,[1] which is so highly important.

It was a contrivance of Bergmann to show the process of chemical preferences in form of diagrams, in the following manner. Let a portion of chalk or marble, which is composed of carbonic acid gas, and lime, be put into a glass tumbler, and some sulphuric acid poured over it. The result will be, that the lime, preferring the sulphuric acid, will go to it, and form plaster of Paris, or gypsum, while the carbonic acid gas will be set free and escape. Mr. R. Phillips ingeniously prints the results in italics, thus:—



When more elements enter into the compounds of substances whose preferences are to be tried, the force of the preferences may be represented by numbers. Kirwan proposed the term *quiescent*, to express preferences[2] already shown by an existing combination; and *divellent*, to express preferences[3] shown by seiz-

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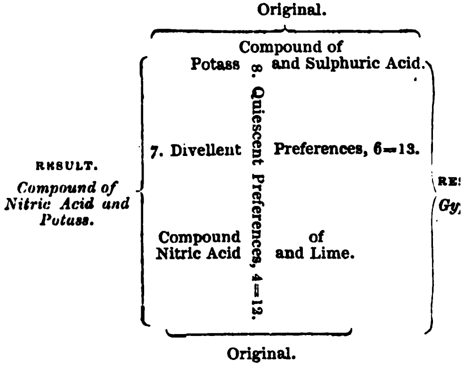
(1) This will be taken up in the "ALPHABET OF CHEMICAL TESTS."

(2) Technically, *Quiescent affinity*.

(3) Technically, *Divellent affinity*, which in one sense is contradictory.

ing and separating the constituents of quiescent pounds ; but these terms are liable to lead to e In the case of the compound of potass and sulpl acid[1], if it be required to separate the acid fron alkali, and lime be added with the intention of un with the acid, the intention will be in vain, as preference which, as proposed by Dr. Henry, ma numbered 8, is greater between the sulphuric acic the potass, than between that and the lime, which be numbered 6. Nitric acid, again, numbered 7 be equally insufficient; but by combining the acid with lime[2], whose preference is numbered 4 adding it to the compound numbered 8, we hav which is less than 7 added to 6, by 1 ; and h the original preferences will be overcome by a of one, as in the following diagram.



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[1] Technically, *Sulphate of potass.*

[2] Technically, *Nitrate of lime.*

The results then will be gypsum (1), composed of lime and the sulphuric acid, originally united with the potass, and a compound of the potass thus set free with the nitric acid (2) originally united with the lime.

LAWS OF CHEMICAL PROPORTIONS.

HOMBERG and Bergmann seem to have been the first chemists who attempted to determine the constituents of salts and other compounds with respect to their relative quantities (3); but they had no notion of these constituents being in any constant proportion as to weight or bulk.

The German chemist, Wenzel, in 1777, was the first to get a glimpse of the doctrine of chemical proportions, from observing a singular circumstance in such cases of decomposition as the one in page 134 above, in which the two neutral salts form exactly two other neutral salts, without excess or the contrary of any of the constituents. That is, supposing there were in the case referred to, of

	Parts by Weight.
Nitric acid . . .	54
Lime	28
Making the compound . .	82

---

(1) Technically, *Sulphate of lime.*

(2) Technically, *Nitrate of potass.*

(3) Technically, or rather pedantically, *Quantitative analysis.* Analysis is from the Greek *ἀναλυω*, "I unloose," or "resolve," meaning, unloosing or resolving.

And of

	Parts by Weight.
Potass	48
Sulphuric acid	40
Making the compound	88

There would result, from the decomposition, the following, namely, of

	Parts by Weight.
Nitric acid	54
Potass	48
Making the compound	102

And of

Sulphuric acid	40
Lime	28
Making the compound	68

the sum of the original numbers 82 added to 88 being exactly 160, the same as the sum of the resulting compounds, 102 added to 68, equalling 160. This important discovery of Wenzel, however, was quite neglected, till similar researches were still farther followed up by Richter, who published several illustrations thereof, in 1792, at Breslau, but he wanted the accuracy of Wenzel, wrote mystically, and from these and other causes, little notice was taken of his labours.

Important Discovery by Dalton.

Mr. Higgins, of Dublin, in 1789, stated, that in pure sulphuric acid every single particle of sulphur is combined with two particles of oxygen, and he reasoned in the same way respecting water, though he vidently was unaware of the importance of these views; but, like what was published by Wenzel and Richter, this statement attracted no notice; and Mr. Dalton, of Manchester, does not appear to have been aware of any of these publications when he began his researches. The first public notice of Dalton's views were given by Dr. Thomson, in the third edition of his System, in 1807, obtained, in 1804, from conversing with Dalton himself, who, in 1808, published his own account of his doctrine in his Chemical Philosophy. It will be most convenient for my present purpose to give the results of the investigations to which Dalton's views have led, rather than to trace their development in the order of time.

Dalton is of opinion that the minute particles or atoms of all simple substances are indivisible, which is probable, but by no means proved, and of a round or globular form, for which he has invented certain symbols, the better to simplify his doctrine[1] of proportional combinations, thus—

○ Oxygen.	⊘ Nitrogen.
⊙ Hydrogen.	● Carbon.

When there is a twofold[2] combination of any of these, he accordingly represents it by the symbols of the constituents, as in the case of water and ammonia, which are composed of—

⊙ Hydrogen. ○ Oxygen.	○ ⊙	Water.
⊙ Hydrogen. ⊘ Nitrogen.	⊘ ⊙	Ammonia.

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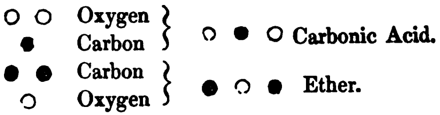
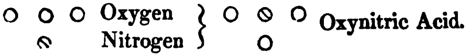
(1) Technically, *The Atomic Theory*.

(2) Technically, *Binary*.

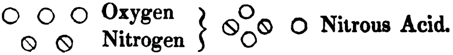
When there is a threefold[1] combination, he represents it as in the case of carbonic acid and ether, thus—



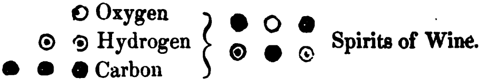
When there is a fourfold[2] combination, he represents it, as in the case of oxynitric acid, thus—



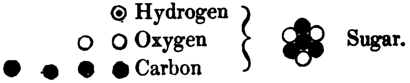
When there is a fivefold[3] compound, he represents it, as in the case of nitrous acid, thus—



When there is a sixfold[4] combination, he represents it, as in the case of spirits of wine[5], thus—



When there is a sevenfold[6] combination, he represents it as in sugar, thus—



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(1) Technically, *Ternary*. (2) Technically, *Quaternary*.

(3) Technically, *Quinquenary*.

(4) Technically, *Sextenary*.

(5) Technically, *Alcohol*, an Arabic word.

(6) Technically, *Septenary*.

The constituents of a compound become, by this simple method, apparent at sight. Berzelius has employed letters for the same purpose, and the idea is good, as affording facilities for algebraic calculation; but unfortunately the mode, in which Berzelius employs his letters, violates all the rules of algebra, as has justly been remarked by Professor Whewell, who, following the example of Sir John Herschell, has proposed a set of symbolical letters free from the fault of Berzelius.

It having been thus shrewdly conjectured by Dalton, and since fully proved by himself, by Dr. Thomson, and others, that besides combining particle to particle singly, one particle of oxygen may combine with 2, 3, 4, or more of hydrogen, of carbon, or of other substances, and hence those proportions become a matter of interesting calculation, to determine the relative weights of the several particles. In the case of water, for example, it is found that it is composed of one particle of oxygen and one particle of hydrogen; but when the weights of these are taken, it is farther found that the oxygen weighs eight times as much as the hydrogen. Dalton, accordingly made choice of the number 1 to express the relative weight of hydrogen, which is the lightest substance known; and though he did not succeed in exactly determining the relative weight of oxygen, it has since been proved by Dr. Thomson, to be exactly 8. It hence becomes one of the most important things in chemistry to determine the weight of a particle of every simple substance as compared with a particle of all the other simple substances, for when this has been done, the results of experiments may often be anticipated, and discoveries of the highest interest may be effected.

It is unfortunate for science, that the most eminent chemists have not agreed in adopting the same series of relative numbers. Instead, for instance, of making hydrogen 1, as is done by Dalton, Dr. Wollaston makes it 1. 25 and oxygen 10; Dr. Thomson makes oxygen 1 and hydrogen 0.125; and Berzelius makes oxygen 100 and hydrogen 12.5. This, however, does not in any way affect the proportional weight of a particle of oxygen being eight times heavier than a particle of hydrogen. I think it preferable to adhere to Dalton's proportions, adopted by Henry, Turner, R. Phillips, and others, as more convenient and perspicuous by avoiding fractional parts.

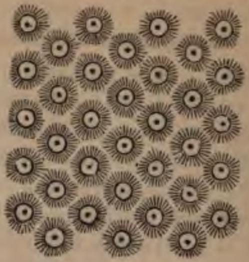
The proportions then, of the constituents of any compound, are always the same, and cannot be altered by adding more of any of these constituents. Sulphuric acid, for example, is always composed of exactly sixteen parts by weight of sulphur and twenty-four parts by weight of oxygen, these twenty-four parts being formed of three particles of oxygen. When one of these particles of oxygen is abstracted, the character of the compound is changed, and we have then sulphurous acid composed of sixteen parts of sulphur and sixteen parts of oxygen. These several numbers, it may be remarked, are always mutually *proportional*, and were hence, by Dr. Wollaston, termed *Equivalents*.

M. Gay-Lussac's Discovery.

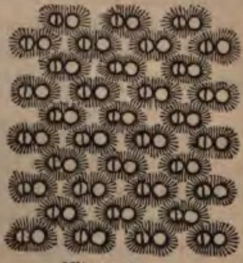
The previous laws of proportional combinations refer to the relative weight of the combining particles; but very soon after the publication of Dalton's views, in 1808, it was discovered by M. Gay-Lussac, that similar laws occur, at least with respect to gases, in the proportional combination of their bulks or measures, or, as he termed it, their *volumes*. Accordingly he found, in conjunction with Baron Humboldt, that water is composed exactly of one measure of oxygen and two measures of hydrogen; and M. A. Berthollet found that ammonia is composed exactly of one measure of nitrogen, and three measures of hydrogen.

M. Gay-Lussac farther discovered that in such combinations there is a diminution in bulk, which is also regulated by the laws of proportion. In the case of ammonia, for example, instead of the one measure of nitrogen, and the three measures of hydrogen, forming four measures, they contract in bulk, by uniting, and form only two measures; and in carbonic acid, formed of one measure of oxygen, and one measure of the vapour of carbon, they contract to one half, and form only one measure of carbonic acid.

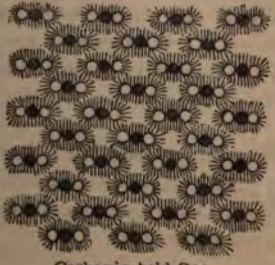
The representations which Mr. Dalton has given of three of the gases as figured on the next page, will aid the conception of the beginner in comprehending some *of the preceding* views.



Hydrogen Gas.



Nitrous Gas.



Carbonic Acid Gas.

TERMS AND LANGUAGE[1] OF CHEMISTRY.

THE brilliant discoveries in chemistry, which rapidly succeeded one another towards the end of the last century, rendered it indispensable to invent names for the substances which had not been previously known; and at first more than one name was given to several of the new substances by different chemists. To prevent the confusion inseparable from such differences, it occurred first, as it would appear, to M. Guyton de Morveau, to proceed in forming such names upon a regular system, and upon such principles he gave a public course of lectures in 1780. Seven years after this, having submitted his views respecting chemical terms to the French Academy, they appointed Lavoisier, Berthollet, and Fourcroy, to examine it and draw up a report of it, which has since, with few alterations, been universally adopted.

Discarding the terms formed on the principles of Stahl's doctrine of phlogiston, they adopted, as we have before explained, the terms oxygen, hydrogen, and nitrogen, for the three newly discovered gases, and though recent discoveries render some of these at present not quite so appropriate, nobody would now dream of changing them. The French chemists

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(1) Technically, *Nomenclature*, from the Latin, *nomen*, "a name," and "*calare*," to call.

made choice of certain terminations added to these words to express their several combinations with others, and similar terminations to other simple substances, with the same view of indicating their composition at sight. When oxygen accordingly formed an acid by uniting with another substance, the name of that substance was terminated in *ic*, as in sulphur*ic* acid, composed of sulphur and oxygen; nitr*ic* acid, formed of nitre and oxygen; and phosphor*ic* acid, formed of phosphorus and oxygen. When the oxygen was in smaller proportion, the termination *ous* was used, as in sulphur*ous* acid, nitr*ous* acid, and phosphor*ous* acid.

When these acids united again with an alkali or an alkaline earth, the termination *ic* was changed to *ate*, as in sulph*ate* of soda, nitr*ate* of lime, phosph*ate* of potass; while the termination *ous* was in the same way changed into *ite*, as in sulph*ite* of potass, formed of sulphurous acid and potass.

When the oxygen combined with any metal or other substance without forming an acid, the termination *ide* or *yde* was used, as in ox*ide* or ox*yde* of iron, and this termination *ide* is now used for combinations of chlorine, iodine, bromine, fluorine, and cyanogen with other substances.

The termination *uret* was used to express the combination of non-metallic substances, either with one another or with metallic oxides, as in sulph*uret* of iron, carb*uret* of iron. Upon this principle, then, we can either say phosphuret of iodine, or iod*uret* of phosphorus.

The doctrine of proportional combinations has introduced still greater precision into this excellent formation of terms. In the instance of salts, when neither the acid nor alkali were in excess, they were termed *neutral*, as in sulphate of magnesia; but if the acid was in excess, the term *super*, *hyper*, or *per* was placed before it, as *per*sulphate of mercury. On the other hand, when the acid was deficient, and the base in excess, the term *sub* or *hypo* was placed before it, as *sub*sulphate of potass. The same terms *super*, *per*, and *sub*, were, and still are, sometimes prefixed to oxides, chlorides, and other terms for compound substances, as *per*chloride of mercury, to indicate the highest proportional of the substance known to enter into combination.

These terms, however, are rapidly giving place, at least in the older and more vague sense, to those indicating numbers, namely, *deuto*, *bis*, or *bi* for two; *ter* for three; *quater* or *quadra* for four, and the like, applied to two, three, or more proportionals of acids; and Dr. Thomson proposes, *dis*, *tris*, and *tetrakis*, &c., to signify two, three, or more proportionals of a base. Thus, what was formerly termed *per*sulphate of potass is now *bi*sulphate of potass. What was formerly *super*oxalate of potass, is *bin*oxalate of potass. What was formerly *per*oxalate of potass, is now *quadro*-oxalate; and what was formerly *sub*sulphate of alumina, is now *di*sulphate of alumina. When there is no prefix, the compound is formed of two proportionals only, sometimes expressed by the prefix *proto*, as *proto*sulphate of iron. The prefix *sesqui*, which means one and a half, is used when the relative proportion of one of the constituents is one and a half, as in *sesqui*carbonate of potass.

"To distinguish," says Dr. Thomson, "the combinations of what are called sulphur acids, &c., from alkaline basis, I have of late made an alteration in the terminations of the old word *sulphuret*, employed to denote the combination of sulphur with a base. Thus *sulphide* of arsenic means an acid formed by the union of sulphur and arsenic; *sulphuret* of copper means an alkaline body formed by the union of sulphur and copper. The term *sulphide* implies an *acid*, the term *sulphuret* a *base*. This mode of naming has become necessary, as without it many of these new salts could not be described in an intelligible manner."

The structure of these terms will, however, be better understood by going over the simple substances and some of their combinations, to which I shall both add the numbers expressing their proportional weights, after Dalton's and Thomson's principle, and the algebraic symbols of Sir John Herschel and Professor Whewell, as they are so much preferable to those of Berzelius, which, however, I have also given.

E SUBSTANCES, WITH THEIR PROPORTIONAL WEIGHTS AND CHIEF COMPOUNDS.

le substances are printed in Roman small capitals, as CARBON; the
mpounds in Italic small capitals, as *CYANOGEN*, *POTASS;* and the
compounds in small italics, as *Peroxide of Gold.* The propor-
its are taken from the best and most recent authorities—Thomson,
Turner, Ure, Gay Lussac, Rose, and others. I have added to
nbols those for Chlorine, Iodine, Bromine, Boron, Selenium, and
hich I am not aware that Dalton himself has hitherto symbolized.
ifficulty of compressing them into a small compass, I have not
Dalton's symbols for the subordinate compounds, but they may
onstructed in any required case from Whewell's formulæ. In the
ibers varying from different authorities, I have given, as in Phos-
in one column and another in another.

SIMPLE SUBSTANCES.

.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
N cides, vater.		*o*	O	8	1
EN rates, and s.		*h*	H	1	0·125
EN, oxy- s ni- d ni-		*n*	N	14	1·75
NE lo- chlo- al*ong* *n,* *tes.*		*cl*	Cl	36	4·5

NAME.	SYMBOLS.			PROPORTIONAL	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxy
Iodine Forms iodides and iodurets, and along with oxygen, forms iodates.		*io*	I	124	15·
Bromine Forms bromides and bromurets, and along with oxygen, forms bromates.		*br*	Br	78·26	9
Carbon Forms carburets, and along with oxygen, forms carbonates.	●	*c*	C	6	0·
Boron Forms borates, and forms, with chlorine,		*b*	B	8	1
Chloride of B.		*cl* *b + cl*	Cl B 2 Cl	36 44	4 5
Sulphur Forms sulphurets, and along with oxygen, forms sulphates and sulphites.	⊕	*s*	S	16	2
Phosphorus Forms phosphurets, and along with oxygen, ms phos- es and phos-		*p*	P	15·71	1

L

ME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
ENIUM seleniu- id along ygen, eleniates.	⊛	*se*	Se	40	5
ORINE fluorides, ng with , forms	Ⓨ	*fl*	Fl	18·86	2·25
YOGEN cyanides nurets, ng with , forms s.	●◉●	2 *c*+*n*	2 Nc	26	3·25

METALS.

METALS WHOSE OXIDES ARE REDUCIBLE TO THE METALLIC STATE BY A RED HEAT.

OLD	Ⓖ	*au*	Au	200	25
s with gen,	○	*o*	O	8	7
ide of		*au* + *o*	$2\,\dot{\mathrm{Au}}$	208	26
ride of		*au* + 2 *o*	$2\,\ddot{\mathrm{Au}}$	216	27
ide of G.		*au* + 3 *o*	$2\,\dddot{\mathrm{Au}}$	224	28
s with orine, *hloride*	⊙	*cl*	Cl	36	4·5
.		*au* + *cl*	Au 2 Cl	236	29·5

NAME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1
Perchloride of G.		*au* + 2 *cl*	$\text{Au}\,2\,\ddot{\text{C}}\text{l}\,2$	272	34
Forms with Iodine,	⊙	*io*	I	124	15.5
Iodide of G.		*au*+*io*	Au 2 I	324	40.5
Forms with Sulphur,	⊕				
Sulphuret of G.		*au* + 3*s*	Au 2 S	216	27
PLATINUM	Ⓟ	*pt*	Pt	96	12
Forms with Oxygen,	○	*o*	O	8	1
Protoxide of P.		*pt* + *o*	2 Pt	104	13
Deutoxide or *Peroxide of P.*		*pt*+2 *o*	$2\,\ddot{\text{P}}\text{t}$	112	14
Forms with Chlorine,	⊙	*cl*	Cl	36	4.5
Protochloride of P.		*pt*+*cl*	$\text{Pt}\,2\,\dot{\text{C}}\text{l}$	132	17.5
Bichloride of P.		*pt*+2 *cl*	$\text{Pt}\,2\,\ddot{\text{C}}\text{l}$	168	21
Forms with Sulphur,	⊕				
Sulphuret of P.		*pt*+*s*	Pt 2 S	112	14
Hydrosulphuret of P.		*pt*+*s*+*wa*	$\text{Pt}\,2\,\text{S}\,2\,\dot{\text{H}}$	121	15·25
Forms with Phosphorus,	⊗	*p*	P	15.71	1.5
Phosphuret of P.		*pt*+*p*		111.5	13.5
SILVER	Ⓢ	*ag*	Ag	110	13·75
ms with ygen,	○	*o*	O	8	1

.ME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
of S.		*ag+o*	2 $\dot{Ag}$	118	14·75
ide of S.		*ag+½ o*	2 Ag	114	14·25
ıs with orine,	⊙	*cl*	Cl	36	4.5
ide of S.		*ag + cl*	Ag 2 Cl	146	18·25
ıs with dine,	⊙	*io*	I	124	15.6
of S.		*ag + io*	Ag 2 I	234	29·25
ıs with phur, *uret of*	⊕	*o*	S	16	2
		ag + s	Ag 2 S	126	15·75
s with phorus, *huret of*	Ⓨ	*p*	P	15.71	1.6
		ag + p	Ag 2 P	125.71	14·25
s with ıogen, *wret of*	●◎●	2 *c+n*	2 N C	26	3.25
		ag + 2 *c + n*	Ag 2 NC	136	17
RCURY	⊙	*hg*	Hg	200	25
s with ygen, *ride of*	○	*o*	O	8	1
		hg + o	2 $\dot{Hg}$	208	26
ide of		*hg* + 2 *o*	2 $\ddot{Hg}$	216	27
s with orine, *chloride f.*†	⊙	*cl*	Cl	15.71	1.5
		hg + cl	Hg 2 $\dot{Cl}$	236	29.5
ride or *chloride f*‡		*hg* + 2 *cl*	Hg 2 $\ddot{Cl}$	272	33

pularly *Red precipitate.* † Popularly Cinnabar or Vermilion.
‡ Popularly *Calomel.*

NAME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
Forms with Iodine,	⊙	*io*	I	124	15.5
Protiodide of M.		*hg + io*	$Hg\ 2\ \dot{I}$	324	40·5
Biniodide of M.		*hg + 2 io*	$Hg\ 2\ \ddot{I}$	448	56
Forms with Sulphur,	⊕	*s*	S	16	2
Protosulphuret of M.		*hg + s*	$Hg\ 2\ \dot{S}$	216	27
Bisulphuret * *of M.*		*hg + 2 s*	$Hg\ 2\ \ddot{S}$	232	29
Forms with Cyanogen,	●◉●	2 *c + n*	2 NC	26	3.25
Cyanuret of M.		*hg* + 2 *c + n*	Hg 2 NC	226	28·25
PALLADIUM	Pd	*pd*	Pd	56	7
Forms with Oxygen,	○	*o*	O	8	1
Protoxide of P.		*pd + o*	$2\ \dot{Pd}$	64	8
Peroxide of P.		*pd* + 2 *o*	$2\ \ddot{Pd}$	72	9
Forms with Chlorine,	⊙	*cl*	Cl	36	4·5
Protochloride of P.		*pd + cl*	$Pd\ 2\ \dot{Cl}$	92	11·5
Bichloride of P.		*pd* + 2 *cl*	$Pd\ 2\ \ddot{Cl}$	128	16
Forms with Sulphur,	⊕	*s*	S	16	2
Sulphuret of P.		*pd + s*	Pd 2 S	72	9
RHODIUM	R	*rh*	R	44	5·5
rms with ygen,	○	*o*	O	8	1

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* Popularly, Corrosive Sublimate.

E.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
de of		*rh+o*	$2\dot{\mathrm{R}}$	52	6·5
le of R.		*rh+2 o*	$2\ddot{\mathrm{R}}$	60	7·5
with rine,	⊙	*cl*	Cl	36	4.5
loride		*rh+cl*	R 2 Cl	80	10
hlo- *of R.*		*rh+$\frac{3}{2}$ cl*		98	12·25
IUM	Ir	*ir*	Ir	30	3·75
with gen,	○	*o*	O	8	1
de of I.		*ir+o*	$2\dot{\mathrm{Ir}}$	38	4·75
le of I.		*ir+2 o*	$2\ddot{\mathrm{Ir}}$	46	5·75
s with rine,	⊙	*cl*	Cl	36	4.5
e of I.		*ir+cl*	Ir 2 Cl	96	8·25
with hur,	⊕	*s*	S	16	2
ret of I.		*ir+s*	Ir 2 S	46	5·75
IUM	Om	*om*	Om	99	12·37
with gen,	○	*o*	O	8	1
de of		*om+o*	$2\dot{\mathrm{Om}}$	107	13·37
ride of		*om+$\frac{3}{2}$ o*		111	14·87
ide of		*om+2 o*	$2\ddot{\mathrm{Om}}$	115	14·37
le of		*om+3 o*	$2\dddot{\mathrm{Om}}$	123	15·37
le of O.		*om+4 o*	2 Om	131	16·37
with ne,	⊙	*cl*	Cl	36	4·5

NAME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
Protochloride of O.		*om + cl*	Om 2 Cl	135	16·87
Bichloride of O.		*om+2 cl*	Om 2 $\ddot{\text{Cl}}$	171	21·37
Terchloride of O.		*om+3 cl*	Om 2 $\dddot{\text{Cl}}$	207	25·87
Perchloride of O.		*om+4 cl*	Om 2 $\ddddot{\text{Cl}}$	243	30.37
Forms with Sulphur,		*s*	S	16	2
Protosulphuret of O.		*om+s*	Om 2 $\dot{\text{S}}$	115	14·37
Sesquisulphuret of O.		*om*+$\frac{3}{2}$ *s*		123	15·37
Bisulphuret of O.		*om+2 s*	Om 2 $\ddot{\text{S}}$	131	16·37
Trisulphuret of O.		*om+3 s*	Om 2 $\dddot{\text{S}}$	147	18·37
Persulphuret of O.		*om+4 s*	Om 2 $\ddddot{\text{S}}$	163	20·37
PLURANIUM.	·	*pl*	Pl	?	?
Compounds unknown.					
RHUTENIUM.		*rm*	Rm	?	?
Compounds unknown.					

II. METALS WHICH DO NOT DECOMPOSE WATER, AND WHOSE OXIDES ARE NOT REDUCIBLE TO THE METALLIC STATE BY HEAT ALONE.

ARSENIC		*ar*	As	38	4·75
Forms with Oxygen,		*o*	O	8	1
enic acid,		*ar*+$\frac{5}{2}$ *o*		60	7·75
mious d.		*ar*+$\frac{3}{2}$ o		52	6.75

NAME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
Forms with Chlorine,		*cl*	Cl	36	4·5
Protochloride of A.		*ar+cl*	As 2 $\dot{\text{Cl}}$	74	8·25
Forms with Iodine,		*io*	I	124	15·5
Iodide of A.		*ar+io*	I 2 As	162	20.25
Forms with Bromine,		*br*	Br	78·26	9·78
Bromide of A.		*ar+br*	As 2 Br	116.26	14·53
Forms with Sulphur,	⊕	*s*	S	16	2
Protosulphuret of A.[*]		*a+rs*	As 2 $\dot{\text{S}}$	54	6·75
Sesquisulphuret of A.[†]		*ar*+$\frac{3}{2}$ *s*		62	7·75
Persulphuret of A.		*ar*+$\frac{5}{2}$ *s*		78	9·75
Forms with Hydrogen, *Arseniuretted Hydrogen.*	⊙	*h*	H	1	0·125
CHROMIUM,	Ⓒ	*cr*	Cr	28	3.5
Forms with Oxygen,	○	*o*	O	8	1
Protoxide of C.		*cr+o*	2 Cr	36	4·5
Chromic acid.		*cr*+$\frac{3}{2}$ *o*		40	5
Forms with Chlorine,		*cl*	Cl	36	4·5
Protochloride of C.		*cr+cl*	Cr 2 $\dot{\text{Cl}}$	64	8
Chlorochromic acid gas.					

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[*] Popularly *Realgar.*

[†] Popularly Orpiment or King's Yellow.

NAME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
Forms with Sulphur,	⊕	*s*	S	16	2
Sulphuret of C.		*cr+s*	Cr 2 S	44	5·5
Forms with Phophorus,	☮	*p*	P	15·71	1·5
Phosphuret of C.		*cr+p*	Cr 2 P	43·71	5
Forms with Fluorine, *Fluochromic acid gas.*	⏀	*fl*	Fl	15·86	2·25
MOLYBDENUM.	Mo	*mo*	Mo	48	6
Forms with Oxygen,	○	*o*	O	8	1
Protoxide of M.		*mo+o*	$2\,\dot{Mo}$	56	7
Deutoxide of M. or *Molybdic acid.*		*mo+2 o*	$2\,\ddot{Mo}$	64	8
Molybdous acid.		*mo+3 o*	$2\,\dddot{Mo}$	72	9
Forms with Chlorine,	⊙	*cl*	Cl	36	4·5
rotochloride of M.		*mo+cl*	$Mo\,2\,\dot{Cl}$	84	10·5
Bichloride of M.		*mo+2 cl*	$Mo\,2\,\ddot{Cl}$	120	15
Perchloride of M.		*mo+3 cl*	$Mo\,2\,\dddot{Cl}$	156	19·5
Forms with phur,	⊕	*s*	S	16	2
lphu- M.		*mo+s*	$Mo\,2\,\dot{S}$	64	8
et		*mo+2 s*	$Mo\,2\,\ddot{S}$	80	10

NAME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
TUNGSTEN	Tu	*tu*	Tu	124	15·75
Forms with Oxygen,	○	*o*	O	8	1
Oxide of T.		*tu+o*	$2\,\dot{\mathrm{Tu}}$	132	16·75
Tungstic acid.		*tu+2 o*	$2\,\ddot{\mathrm{Tu}}$	158	18·75
Forms with Chlorine,	⊙	*cl*	Cl	36	4·5
Bichloride of T.		*tu+2 cl*	$\mathrm{Tu}\ 2\,\ddot{\mathrm{Cl}}$	196	24·75
Perchloride of T.		*tu+3 cl*	$\mathrm{Tu}\ 2\,\dddot{\mathrm{Cl}}$	232	29.25
COLUMBIUM.	Cm	*cm*	Cm	144	18
Forms with Oxygen,	○	*o*	O	8	1
Oxide of C. or *Columbic acid.*		*cm+o*	$2\,\dot{\mathrm{Cm}}$	152	19
Forms with Chlorine,	⊙	*cl*	Cl	36	4·5
Chloride of C.		*cm+cl*	Cm 2 Cl	180	22.5
Forms with Sulphur,	⊕	*s*	S	16	2
Sulphuret of C.		*cm+s*	Cm 2 S	160	20
Forms with Fluorine,	Ⓨ	*fl*	Fl	18·86	2·25
Fluoride of C.		*cm+fl*	Cm 2 Fl	162·86	20·25
ANTIMONY	An	*an*	An	44	5·5
Forms with Oxygen,	○	*o*	O	8	1
*Protoxide of A.**		*an+o*	$2\,\dot{\mathrm{An}}$	52	6·5

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* Formerly, *Powder of Algaroth.*

NAME.	SYMBOLS.			PROPORTIONAL WG	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen
*Deutoxide of A.** or *Antimonious acid.*		$an+\frac{3}{2}o$		56	7
Peroxide of A. or *Antimonic acid.*		$an+2o$	$2\,\ddot{An}$	60	7·5
Forms with Chlorine,	⊙	cl	Cl	36	4·5
Protochloride of A.†		$an+cl$	$An\,2\,\dot{Cl}$	80	10
Bichloride of A.		$an+2\,cl$	$An\,2\,\ddot{Cl}$	116	14·5
Dichloride of A.				124	15·5
Forms with Bromine,	⦶	br	Br	78·26	9·78
Bromide of A.		$an+br$	An 2 Br	122·26	15·28
Forms with Sulphur,	⊕	s	S	16	2
Protosulphuret of A.		$an+s$	$An\,2\,\dot{S}$	60	7·5
Sesquisulphuret of A.		$an+\frac{3}{2}s$			
Bisulphuret of A.		$an+2\,s$	$An\,2\,\ddot{S}$	68	8·5
Oxysulphuret of A.				76	10·5
Hydro-oxysulphuret of A.‡				96	12
URANIUM.	Ⓤ	ur	Ur	208	26
Forms with Oxygen,	○	o	O	8	1
Protoxide of U.		$ur+o$	$2\,\dot{Ur}$	216	27

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* By apothecaries, *Antimonial powder*.

merly, *Butter of antimony*.

‡ Formerly, Kermes miner

AME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
ride of		$ur+\frac{3}{2}o$		220	27·5
ms with lphur,	⊕	s	S	16	2
huret of		$ur+s$	Ur 2 S	224	28
ERIUM.	Ce	ce	Ce	50	6·25
ms with xygen,	○	o	O	8	1
oxide of		$ce+o$	$2\,\dot{\mathrm{Ce}}$	58	7·25
oxide of		$ce+2\,o$	$2\,\ddot{\mathrm{Ce}}$	66	8·25
ms with lphur,	⊕	s	S	16	2
huret of		$ce+s$	Ce 2 S	66	8·25
SMUTH.	Ⓑ	bi	Bi	72	9
ms with xygen,	○	o	O	8	1
xide of		$bi+o$	2 Bi	80	10
ms with lorine,	⊙	cl	Cl	36	4·5
ide of B.		$bi+c$	Bi 2 Cl	108	13·5
ns with omine,	⦶	br	Br	78·26	9·78
ide of B.		$bi+br$	Bi 2 Br	150·26	18.78
s with lphur,	⊕	s	S	16	2
uret of		$bi+s$	Bi 2 S	88	11
ANIUM.	Ti	ti	Ti	32	4
ns with ygen,	○	o	O	8	1

NAME.	SYMBOLS.			PROPORTIONAL W	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen
Protoxide of T.		*ti+o*	$2\dot{Ti}$	40	5
Peroxide of T. or *Titanic acid.*		*ti+2 o*	$2\ddot{Ti}$	48	6
Forms with Chlorine,	(··)	*cl*	Cl	36	4·5
Chloride of T.		*ti+cl*	Ti 2 Cl	68	8·5
Forms with Sulphur,	⊕	*s*	S	16	2
Sulphuret of T.		*ti+s*	Ti 2 S	48	6
TELLURIUM.	(Te)	*te*	Te	32	4
Forms with Oxygen,	○	*o*	O	8	1
Oxide of T.		*te+o*	2 Te	40	5
Forms with Chlorine,	(··)	*cl*	Cl	36	4·5
Chloride of T.		*te+cl*	Te 2 Cl	68	8.5
Forms with Hydrogen,	⊙	*h*	H	1	0·12
Hydruret of T. or *Telluretted hydrogen gas.*		*te+h*	Te 2 H	33	4.12
COPPER.	Ⓒ	*cu*	Cu	64	8
Forms with Oxygen,	○	*o*	O	8	1
Protoxide of C.		*cu+o*	$2\dot{Cu}$	72	9
Peroxide of C.		*cu+2 o*	$2\ddot{Cu}$	80	10
orms with hlorine,	(··)	*cl*	Cl	36	4·5
chloride		*cu+cl*	Cu 2 $\dot{Cl}$	100	12·5

B.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	**Whewell.**	**Berzelius.**	**Oxygen 8.**	**Oxygen 1.**
ride		*cu*+2 *cl*	Cu 2 $\ddot{\mathrm{Cl}}$	136	17
with hur,	⊕	*s*	S	16	2
lphu- *C.*		*cu*+*s*	Cu 2 $\dot{\mathrm{S}}$	80	10
uret		*cu*+2 *s*	Cu 2 $\ddot{\mathrm{S}}$	96	12
with orus,	Ⓨ	*p*	P	15·71	1·5
uret of		*cu*+*p*	Cu 2 P	79·71	9·5
D.	Ⓛ	*pb*	Pb	104	13
with en,	○	*o*	O	8	1
le of		*pb*+*o*	2 $\dot{\mathrm{Pb}}$	112	14
ie of		*pb*+$\frac{3}{2}$ *o*		116	14·5
r of		*pb*+2 *o*	2 $\ddot{\mathrm{Pb}}$	120	15
with ne,	⊙	*cl*	CL	36	4·5
of		*pb*+*cl*	Pb 2 Cl	140	17·5
with e,	⊛	*io*	I	124	15·5
L.		*pb*+*io*	Pb 2 I	128	18·5
vith n,	●	*c*	C	6	0·75
of		*pb*+*c*	Pb 2 C	110	13·75
ith r,	⊕	*s*	S	16	2
t of		*pb*+*s*	Pb 2 S	120	15

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† *Popularly, Red lead*; **in Latin, Minium.**

NAME.	SYMBOLS.			PROPORTI
	Dalt.	Whewell.	Berzelius.	Oxygen 8 .
Forms with Phosphorus,	Ⓨ	*p*	P	15·71
Phosphuret of L.		*pb*+*p*	Pb 2 P	119·71

III. METALS WHICH DECOMPOSE WATER AT A RED HE

MANGANESE.	◒	*mn*	Mn	28
Forms with Oxygen,	○	*o*	O	8
Protoxide of M.		*mn*+*o*	$2\dot{\mathrm{Mn}}$	36
Deutoxide of M.		*mn*+$\frac{3}{2}$*o*		40
Peroxide of M.				
Red oxide of M.		*mn*+2 *o*	$2\ddot{\mathrm{Mn}}$	44
Varvicite.				
Forms with Chlorine,	⊙	*cl*	Cl	36
Chloride of M.		*mn*+*cl*	Mn 2 Cl	64
Forms with Sulphur,	⊕	*s*	S	16
Protosulphuret of M.		*mn*+*s*	Mn 2 S	44
Forms with Phosphorus,	Ⓨ	*p*	P	15·7
Phosphuret of M.		*mn*+*p*	Mn 2 P	43·7
Forms with Fluorine,	Ⓨ	*fl*	Fl	18·8
Fluoride of M.		*mn*+*fl*	Mn 2 Fl	46·8

IE.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
ON.	Ⓘ	*fe*	Fe	28	3·5
s with 'gen,	○	*o*	O	8	1
'ide of		*fe*+*o*	$2\,\dot{\mathrm{Fe}}$	36	4.5
ide of		*fe*+$\frac{3}{2}$ *o*		40	5
oxide of					
ıs with orine, 'hloride	⊙	*cl*	Cl	36	4·5
.		*fe*+*cl*	Fe 2 Cl	64	8
loride of		*fe*+$\frac{3}{2}$ *cl*		82	10·25
ıs with mine, ıromide	⦶	*br*	Br	78·26	9·78
.		*fe*+*br*	Fe 2 Br	106·26	13·28
omide .					
ıs with dine, ' of I.	⊙	*io* *fe*+*io*	I Fe 2 I	124 152	15·5 19
ıs with rbon, :ret of	●	*c*	C	6	0·75
		fe+*c*	Fe 2 C	34	3·75
ıs with phur, rulphu- of I.§	⊕	*s*	S	16	2
		fe+*s*	$\mathrm{Fe}\ 2\ \dot{\mathrm{S}}$	44	5·5
ɔhuret .		*fe*+2 *s*	$\mathrm{Fe}\ 2\ \ddot{\mathrm{S}}$	60	7·5
NC.‖	Ⓩ	*zi*	Zn	34	4·25

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ly, *Blue oxide of Iron*. † Formerly, Red oxide of Iron, popularly, Rust.
arly, *Steel*, *Pig-iron*, and *black-lead*, all of which are carburets
ferent proportions merely.
larly, *Copperas*, or *Green Vitriol*. ‖ Popularly, Spelter.

NAME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
Forms with Oxygen, *Oxide of Z.*	○	*o* *zi+o*	O 2 Zn	8 42	1 5·25
Forms with Chlorine, *Protochloride of Z.*	⊙	*cl* *zi+cl*	Cl Zn 2 Cl	36 70	4·5 8·75
Forms with Iodine, *Iodide of Z.*	⊙	*io* *zi+io*	I Zn 2 I	124 168	15·5 19·75
Forms with Bromine, *Bromide of Z.*	⦶	*br* *zi+br*	Br Zn 2 Br	78·26 112·26	9·78 14·03
Forms with Sulphur, *Sulphuret of Z.*	⊕	*s* *zi+s*	S Zn 2 S	16 50	2 6·25
CADMIUM.	Cd	*cd*	Cd	56	7
Forms with Oxygen, *Oxide of C.*	○	*o* *cd+o*	O 2 Cd	8 64	1 8
Forms with Chlorine, *Chloride of C.*	⊙	*cl* *cd+cl*	Cl Cd 2 Cl	36 92	4·5 11·5
Forms with Iodine, *Iodide of C.*	⊙	*io* *cd+io*	I Cd 2 I	124 180	15·5 22·5
Forms with Sulphur, *Sulphuret of C.*	⊕	*s* *cd+s*	S Cd 2 S	16 72	2 9
Forms with Phosphorus, *Phosphuret of C.*	☮	*p* cd+p	P Cd 2 P	15·71 71·71	1·5 8·5

AME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
TIN.	Ⓣ	*sn*	Sn	58	7·25
ms with xygen,	○	*o*	O	8	1
xide of		*sn+o*	$2\,\dot{\mathrm{Sn}}$	66	8·25
ride of		*sn+2 o*	$2\,\ddot{\mathrm{Sn}}$	74	9·25
ms with lorine,	⊙	*cl*	Cl	36	4·5
chloride *T.*		*sn+cl*	Sn 2 Cl	94	11·75
'oride of		*sn+2 cl*	$\mathrm{Sn}\ 2\,\ddot{\mathrm{Cl}}$	130	16·25
ns with lphur,	⊕	*s*	S	16	2
sulphu- *of T.*		*sn+s*	$\mathrm{Sn}\ 2\,\dot{\mathrm{S}}$	74	9·25
phuret ' *T.*		*sn+2 s*	$\mathrm{Sn}\ 2\,\ddot{\mathrm{S}}$	90	11·25
isulphu- *of T.*		$sn+\frac{3}{2}\,s$		82	10·25
BALT.	Ⓒ	*cb*	Cb	26	3·25
ns with ygen,	○	*o*	O	8	1
xide of		*cb+o*	$2\,\dot{\mathrm{C}}\mathrm{b}$	34	4·25
ride of		$cb+\frac{3}{2}$		38	4.75
ns with lphur,	⊕	*s*	S	16	2
sulphu- *of C.*		*cb+s*	$\mathrm{Cb}\ 2\,\dot{\mathrm{S}}$	42	5.25
lphuret .					
phuret .		*cb+2 s*	$\mathrm{Cb}\ 2\,\ddot{\mathrm{S}}$	58	7·25
s with *rine,*	⊙	*cl*	Cl	36	4·5

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* Popularly, *Mosaic Gold*, in Latin, *Aurum musivum*.

NAME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1
Chloride of C.		$cb+cl$	Cb 2 Cl	62	7·75
Forms with Carbonic acid,		$c+2\,o$		22	2·75
Carbonate of C.		$cb+c+2\,o$		48	6
NICKEL.	Ⓝ	n	Ni	26	3·25
Forms with Oxygen,	○	o	O	8	1
Protoxide of N.		$ni+o$	2 $\dot{\mathrm{Ni}}$	34	4·25
Peroxide of N.		$ni+o\,\frac{3}{2}$		38	4·75
Forms with Sulphur,	⊕	s	S	16	2
Protosulphuret of N.		$ni+s$	Ni 2 $\dot{\mathrm{S}}$	42	5·25
Disulphuret of N.		$ni+3\,s$		74	9.25
Forms with Phosphorus,	Ⓨ	p	P	15·71	1·5
Phosphuret of N.		$ni+p$	Ni 2 P	41·71	4·75

IV. METALS WHOSE OXIDES FORM ALKALIES AND EARTH.

POTASSIUM.	Ⓚ	ka	Ka	40	5
Forms with Oxygen,	○	o	O	8	1
*Protoxide of P.**		$ka+o$	2 $\dot{\mathrm{Ka}}$	48	6
Peroxide of P.		$ka+3\,o$	2 $\dddot{\mathrm{Ka}}$	64	8
Forms with Chlorine,	⊙	cl	Cl	36	4·5
Chloride of P.		$ka+cl$	Ka 2 Cl	76	9·

* Commonly, Potass, or Caustic Potass.

E.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
with ne,	(∴)	*io*	I	124	15·5
f P.		*ka+io*	Ka 2 I	164	20·5
with gen,	⊙	*h*	H	1	0·125
uret .		*ka+h*	Ka 2 H	41	5·125
with hur,	⊕	*s*	S	16	2
lphu- *P.*		*ka+s*	Ka 2 $\dot{S}$	56	7
uret .		*ka+2s*	Ka 2 $\ddot{S}$	62	9
huret .		*ka+3s*	Ka 2 $\dddot{S}$	78	11
sul- *et of P.*		*ka+4s*	Ka 2 $\ddddot{S}$	94	13
huret		*ka+5s*	Ka 2 $\overset{.....}{S}$	120	15
with orus,	Ⓨ	*p*	P	15.71	1·5
uret		*ka+p*	Ka 2 P	55·71	6·5
UM.	Na	*na*	Na	24	3
with en,	○	*o*	O	8	1
de of		*na+o*	` 2 Na	32	4
le of		*na+*$\frac{3}{2}$*o*		36	4·5
with ine,	(··)	*cl*	Cl	36	4·5
e of		*na+cl*	Na 2 Cl	60	7·5
UM.	Li	*li*	Li	10	1·25

, *Soda*, or *Pure Soda*. †Popularly, Salt, formerly, Muriate of Soda.

NAME.	SYMBOLS.			PROPORTIONAL	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxy
Forms with Oxygen,	○	*o*	O	8	
*Protoxide of L.**		*li*+*o*	2 Li	18	
BARIUM.	Ba	*ba*	Ba	70	
Forms with Oxygen,	○	*o*	O	8	
Protoxide of B.†		*ba*+*o*	$2\ \dot{\mathrm{Ba}}$	78	
Deutoxide of B.		*ba*+2 *o*	$2\ \ddot{\mathrm{Ba}}$	86	1
Forms with Chlorine,	⊙	*cl*	Cl	36	
Chloride of B.		*ba*+*cl*	Ba 2 Cl	106	1
Forms with Bromine,	⦶	*br*	Br	78·26	
Bromide of B.		*ba*+*br*	Ba 2 Br	114·26	1
Forms with Sulphur,	⊕	*s*	S	16	
Sulphuret of B.		*ba*+*s*	Ba 2 S	86	1
STRONTIUM.	Sr	*sr*	Sr	44	
Forms with Oxygen,	○	*o*	O	8	
Protoxide of S.‡		*sr*+*o*	$2\ \dot{\mathrm{Sr}}$	52	
Deutoxide of S.		*sr*+2 *o*	$2\ \ddot{\mathrm{Sr}}$	60	
Forms with Chlorine,	⊙	*cl*	Cl	36	
Chloride of S.		*sr*+*cl*	Sr 2 Cl	80	1
Forms with *Sulphur*,	⊕	*s*	S	16	

ommonly, *Lithia*.

† Commonly, *Baryta*.

‡ Commonly

ME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
uret of		*sr+s*	Sr 2 S	60	7·5
CIUM.	(Ca)	*ca*	Ca	20	2·5
ıs with ygen,	○	*o*	O	8	1
ride of		*ca+o*	$2\ \dot{\mathrm{C}}\mathrm{a}$	28	3·5
ride of		*ca+2 o*	$2\ \ddot{\mathrm{C}}\mathrm{a}$	36	4·5
ıs with orine,	(··)	*cl*	Cl	36	4·5
de of C.		*ca+cl*	Ca 2 Cl	56	7
ıs with mine,	(·|·)	*br*	Br	78·26	9.78
de of C.		*ca+br*	Ca 2 Br	98·26	12.28
ıs with phur,	⊕	*s*	S	16	2
ulphu- f C.		*ca+s*	$\mathrm{Ca}\ 2\ \dot{\mathrm{S}}$	36	4·5
ıs with ıhorus,	Ⓨ	*p*	P	15·71	1·5
ıuret of		*ca+p*	Ca 2 P	35·71	4
ESIUM.	(Ma)	*ma*	Ma	12	1·5
s with gen,	○	*o*	O	8	1
of M.†		*ma+o*	2 Ma	20	2·5
s with rine,	(··)	*cl*	Cl	36	4·5
le of		*ma+cl*	Ma 2 Cl	48	6
s with aine,	(·|·)	*br*	Br	78·26	9.78
le of		*ma+br*	Ma 2 Br	90·26	11·28

nmonly, *Lime*, or *Quick-lime*.

† Commonly, Magnesia.

NAME.	SYMBOLS.			PROPORTIONAL	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxy
ALUMINIUM.	Al	*al*	Al	10	
Forms with Oxygen,	○	*o*	O	8	
*Oxide of A.**		*al+o*	2 Al	18	
Forms with Chlorine,	⊙	*cl*	Cl	36	
Chloride of A.		*al+cl*	Al 2 Cl	46	
Forms with Sulphur,	⊕	*s*	S	16	
Sulphuret of A.		*al+s*	Al 2 S	26	
Forms with Phosphorus,	Ⓨ	*p*	P	15.71	
Phosphoret of A.		*al+p*	Al 2 P	25·71	
Forms with Selenium,	⊛	*se*	Se	40	
Seleniuret of A.		*al+se*	Al 2 Se	50	
GLUCINIUM.	Gl	*gl*	Gl	18	
Forms with Oxygen,	○	*o*	O	8	
Oxide of G†		*gl+o*	2 Gl	26	
YTTRIUM.	Yt	*yt*	Yt	34	
Forms with Oxygen,	○	*o*	O	8	
Oxide of Y ‡		*yt+o*	2 Yt	42	
Forms with Sulphur,	⊕	*s*	S	16	
Sulphuret of Y.		*yt+s*	Yt 2 S	50	
Forms with Phosphorus,	Ⓨ	*p*	P	15.71	
Phosphuret of Y.		*yt+p*	Yt 2 P	49·71	

[*] mmonly *Alumina*, or *Pure Clay*. † Commonly, Glucina. ‡ Commonl

NAME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
Forms with Selenium,	⊛	*se*	Se	40	5
Seleniuret of Y.		*yt+se*	Yt 2 Se	70	7·25
THORIUM.	Th	*th*	Th	67·6	8·45
Forms with Oxygen,	○	*o*	O	8	1
*Oxide of T.**		*th+o*	2 Th	75·6	9·45
Forms with Chlorine,	⊙	*cl*	Cl	36	4·5
Chloride of T.		*th+cl*	Th 2 Cl	113·6	11·95
Forms with Sulphur,	⊕	*s*	S	16	2
Sulphuret of T.		*th+s*	Th 2 S	8·6	13·40
Forms with Phosphorus,	Ⓨ	*p*	P	15·78	1·5
Phosphuret of T.		*th+p*	Th 2 P	83·31	9.95
ZIRCONIUM.	Zi	*zi*	Zi	40	5
Forms with Oxygen,	○	*o*	O	8	1
Oxide of Z.†		*zi+o*	2 Zi	48	6
Forms with Sulphur,	⊕	*s*	S	16	2
Sulphuret of Z.		*zi+s*	Zi 2 S	24	3
SILICIUM.	Si	*si*	Si	8	1
Forms with Oxygen,	○	*o*	O	8	1
Oxide of S.‡		*si+o*	2 Si	16	2
Forms with *Chlorine,*	⊙	*cl*	Cl	36	4·5

* Commonly, *Thorina.* † Commonly, *Zirconia.*

‡ Commonly, *Silica*; formerly *Silex*; by Dr. Thomson, *Silicon.*

NAME.	SYMBOLS.			PROPORTIONAL W	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxyge
Chloride of S.		$si+cl$	Si 2 Cl	44	5·
Forms with Sulphur,	○	s	S	16	2
Sulphuret of S.		$si+s$	Si 2 S	24	3
ALKALIES AND EARTHS.					
POTASS.	○	$ka+o$	2 K	48	6
Forms with Water,	○⊙	$h+o$	2 H	9	1·
Hydrate of P.		$h+ka+o$	2 K 2 H	57	7·
Forms with Carbonic acid,		$c+2o$	$\ddot{C}$	22	2·
Carbonate of P.		$ka+o+c+2o$	$2K2\ddot{C}$	70	8·
Sesquicarbo- of P.		$ka+o+\frac{3}{2}c+2o$		81	9.
Bicarbonate P.		$ka+o+2c+2o$	$2K2\ddot{C}2$	92	10.
Forms with Sulphuric acid,		$s+3o$	$\dddot{S}$	40	5
Sulphate of P.		$ka+o+s$	2 K 2 S	88	11
Forms with Phosphoric acid,		$p+\frac{5}{2}o$	$2\overset{\cdot\cdot\cdot\cdot\cdot}{P}$	35·71	4·
Phosphate of P.		$ka+p+\frac{5}{2}o$		83·71	10·
Forms with Chromic acid,		$cr+\frac{5}{2}o$		52	6·
Chromate of P.		$ka+o+cr+\frac{5}{2}o$		100	12.
Bichromate of P.		$ka+o+2cr+\frac{5}{2}o$		152	

	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
ith :id, *ate*		$ar+\frac{3}{2}\text{-}o$		58	7·25
		$ka+o+2\,ar+\frac{3}{2}\,o$		164	20·5
ith id, *ʻ P.*		$n+5\,o$		54	6·75
		$ka+o+n+5\,o$		102	12·75
ith cid,				120	15
				168	21
ith id,				50	6·25
				98	12·25
: of				148	18·5
ith cid, *f*				66	8·25
				114	14.25
' of				180	22·5
ith id,				36	4·5
				84	10·5
e				120	15
e				156	19·5
late				192	24
	⦶	$na+o$	2 Na	32	4
ith :id, *of*		$c+2\,o$	C	22	2·75
		$na+o+c+2\,o$	2 Na 2 C	54	6·75

NAME.	SYMBOLS.			PROPORTIONAL WGT	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen
Sesquicarbonate of S.		$na+o+\frac{3}{2}\,c+2\,o$		65	5·82
Bicarbonate of S.		$na+o+2\,c+2\,o$	$2\,Na\,2\,\ddot{C}\,2$	76	9·5
Forms with Sulphuric acid,		$s+3\,o$	$\dddot{S}$	40	5
*Sulphate of S.**		$na+o+s+3\,o$	$2\,Na\,2\,\dddot{S}$	72	9
Forms with Phosphoric acid,		$p+\frac{5}{2}o$	$2\,\overset{\cdot\cdot}{\dddot{P}}$	35·71	4·46
Phosphate of S.		$na+o+p+\frac{5}{2}\,o$		67.71	8·46
Biphosphate of S.		$na+o+2\,p+\frac{5}{2}\,o$		103·42	15·95
Forms with Nitric acid,		$n+5\,o$		54	6·75
Nitrate of S.		$na+o+n+5\,o$		86	10·75
Forms with Boracic acid,				24	3
Biborate of S.				80	10
Forms with Arsenic acid,		$ar+\frac{5}{2}\,o$		58	7·25
Arseniate of S.		$na+o+ar+\frac{5}{2}\,o$		90	11·25
Biarseniate of S.		$na+o+2\,ar+\frac{5}{2}o$		148	18·2
Forms with Chromic acid,		$cr+\frac{5}{2}\,o$		52	6·6
Chromate of S.		$na+o+2\,cr+\frac{5}{2}o$		186	17·5
Bichromate of S.					
Forms with Columbic acid,		$cm+o$		158	19.75

* Popularly, Glauber's Salts.

NAME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
Columbate of S.		*na+o+cm+o*		190	23·75
Forms with Succinic acid,				50	6·52
Succinate of S.				82	10·25
Forms with Saclactic acid,				104	10·25
Saclactate of S.				136	14.5
Forms with Uric acid,				72	5
Urate of S.				104	12
Forms with Acetic acid,				50	6.25
Acetate of S.				82	10·25
Forms with Tartaric acid,				66	8·25
Tartrate of S.				98	15·25
Forms with Oxalic acid,				36	4.5
Oxalate of S.				68	8·5
Binoxolate of S.				104	13
LITHIA.	Li	*li+o*	2 L	18	2·25
Forms with Carbonic acid,		*c+2 o*	$\dddot{\mathrm{C}}$	22	2·75
Carbonate of L.		*li+o+c+2 o*	2 L 2 $\dddot{\mathrm{C}}$	40	5
Forms with Sulphuric acid,		*s+3 o*	$\dddot{\mathrm{S}}$	40	5
Sulphate of L.		*li+o+s+2 o*	2 L 2 $\dddot{\mathrm{S}}$	58	7·25
Forms with Phosphoric acid,		$p+\frac{5}{2}\,o$	·· 2 $\dddot{\mathrm{P}}$	35·71	4

NAME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
Phosphate of L.		$li+o+p+\frac{5}{2}o$	$2\,L\,2\,\overset{\overset{\cdot\cdot}{\cdot\cdot\cdot}}{P}$	53·71	6·71
AMMONIA.		$n+3\,h$	$2\,N\,2\,\overset{\cdot\cdot\cdot}{H}$	17	2·125
Forms with Carbonic acid,		$c+2\,o$	$\ddot{C}$	22	2·75
Carbonate of A.		$n+3\,h+c+2\,o$		39	4·875
Sesquicarbonate of A.		$n+3\,h+\frac{3}{2}\,c+2\,o$		50	6·25
Bicarbonate of A.		$n+3\,h+2\,c+2\,o$		61	7·625
Forms with Sulphuric acid,		$s+3\,o$	$\overset{\cdot\cdot\cdot}{S}$	40	5
Sulphate of A.		$n+3\,h+s+3\,o$		57	7·125
Forms with Phosphoric acid,		$p+\frac{5}{2}o$	$\overset{\overset{\cdot\cdot}{\cdot\cdot\cdot}}{P}$	95·71	4·46
Phosphate of A.		$n+3\,h+p+\frac{5}{2}o$		52·71	6·585
Biphosphate of A.		$n+3\,h+2\,p+\frac{5}{2}o$		88·42	11·45
Forms with Nitric acid,		$n+5\,o$		54	6·75
Nitrate of A.		$n+3\,h+n+5\,o$		71	8·875
Forms with Arsenic acid,		$ar+\frac{3}{2}\,o$		58	7·25
Arseniate of A.		$n+3\,h+ar+\frac{3}{2}\,o$		75	9·375
Binarseniate of A.		$n+3h+2ar+\frac{3}{2}\,o$		133	16·625
Forms with Chromic acid,		$cr+\frac{5}{2}\,o$		52	6·5
Chromate of A.		$n+3\,h+cr+\frac{5}{2}\,o$		69	8·625
Bichromate of A.		$n+3h+2\,cr+\frac{5}{2}\,o$		121	15·1

E.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
with ic acid, *state*		$tu+3\,o$	$\dddot{W}$	120	15
		$n+3h+2tu+3\,o$		40	32·125
with acid,				24	3
of A.				41	5·125
with c acid, *te of*				120	15
				290	17·125
with c acid, *te of*				50	6·25
				67	8·375
with acid,				50	6.25
of A.				67	8·375
with c acid, *e of*				66	8·25
				80	
with acid, *of*					
late of					
YTA.	✪	$ba+o$	2 Ba	78	9·75
with hloric d,		$cl+h$	2 H Cl	37	4·625
hlorate		$ba+o+cl+h$		115	13·375
with *acid,*		$s+3\,o$	$\dddot{S}$	40	5

nerly, *Muriate of Barytes*; by Painters, Permanent white.

NAME.	SYMBOLS.			PROPORTI
	Dalt.	Whewell.	Berzelius.	Oxygen 8
Sulphate of B.		$ba+o+s+3\,o$		118
Forms with Phosphoric acid,		$p+\frac{3}{2}\,o$	$2\,\overset{\substack{\cdot\cdot\\\cdot\cdot\cdot}}{P}$	35·71
Phosphate of B.				
Biphosphate of B.		$ba+o+2\;p+\frac{5}{2}\,o$		149·52
Forms with Carbonic acid,		$c+2\,o$	$\ddot{C}$	22
Carbonate of B.		$ba+o+c+2\,o$		100
Forms with Nitric acid,		$n+5\,o$	$2\,\overset{\substack{\cdot\cdot\\\cdot\cdot\cdot}}{N}$	54
Nitrate of B.		$ba+o+n+5\,o$		132
Forms with Chromic acid,		$cr+\frac{3}{2}\,o$		52
Chromate of B.		$ba+o+cr+\frac{3}{2}\,o$		130
Forms with Columbic acid,		$cm+o$		152
Sesquicolumbate of B.		$ba+o+\frac{3}{2}\,cm+o$		306
Forms with Acetic acid,				50
Acetate of B.				128
Forms with Tartaric acid,				66
Tartrate of B.				144
Forms with Oxalic acid,				36
Oxalate of C.				114
STRONTIA.		$sr+o$	2 Sr	52
Forms with Carbonic acid,		$c+2\,o$	$\ddot{C}$	22

:.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
te of		$sr+o+c+2\ o$	$2\ Sr\ 2\ \ddot{C}$	74	9·25
with : acid,		$s+3\ o$	$\ddot{S}$	40	5
; of S.		$sr+o+s+3\ o$		92	11·5
with :ic		$p+\frac{5}{2}\ o$	$2\ \overset{\cdot\cdot}{\dddot{P}}$	35·71	4·46
ıte of		$sr+o+p+\frac{5}{2}\ o$		57·71	10·96
with acid,		$n+5\ o$	$2\ \overset{\cdot\cdot}{\dddot{N}}$	54	6·75
of S.		$sr+o+n+5\ o$		106	13·25
with acid,		$ar+\frac{3}{2}\ o$		58	7·25
te of		$sr+o+ar+\frac{3}{2}\ o$		110	13·75
with acid,		$cr+\frac{5}{2}\ o$		52	6·5
te of		$sr+o+cr+\frac{5}{2}\ o$		104	13
with acid,				50	6·25
: of S.				102	12·75
with : acid,				66	8·25
e of				118	14·75
with : acid,				36	4·5
; of S.				88	11
late of				124	15·5
ME.	◎	$ca+o$	$2\ Ca$	28	3·5
with *acid,*		$c+2\ o$	$2\ \ddot{C}$	22	2·75

NAME.	SYMBOLS.			PROPORT
	Dalt.	Whewell.	Berzelius.	Oxygen
Carbonate of L.[*]		$ca+o+c+2\,o$	$2\,Ca\,2\,\dddot{C}$	50
Forms with Sulphuric acid,		$s+3\,o$	$\dddot{S}$	40
Sulphate of L.†		$ca+o+s+3\,o$	$2\,Ca\,2\,\dddot{S}$	68
Forms with Phosphoric acid,		$p+\frac{5}{2}\,o$	$2\,\overset{\cdot\cdot}{\dddot{P}}$	35·71
Phosphate of L.		$ca+o+p+\frac{5}{2}\,o$	$2\,\overset{\cdot\cdot}{\dddot{N}}$	63·71
Forms with Nitric acid,		$n+5\,o$		54
Nitrate of L.		$ca+o+n+5\,o$		82
Forms with Arsenic acid,		$ar+\frac{5}{2}\,o$		58
Arseniate of L.		$ca+o+ar+\frac{5}{2}\,o$		86
Forms with Chromic acid,		$cr+\frac{5}{2}\,o$		52
Chromate of L.		$ca+o+cr+\frac{5}{2}\,o$		80
Forms with Tungstic acid,		$tu+3\,o$	$\dddot{W}$	120
Tungstate of L.		$ca+o+tu+3\,o$		148
Forms with Acetic acid,				50
Acetate of L.				78
Forms with Tartaric acid,				66
Tartrate of L.				94
Forms with Oxalic acid,				36

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[*] Commonly, *Chalk*, *Limestone*, *Marl*, and *Marble*.

† Commonly, *Gypsum*, or *Plaster of Paris*.

ME.	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
te of L.				64	8
NESIA.	⊛	$ma+o$	2 Mg	20	2·5
ns with ochloric		$c\acute{l}+h$	2 H Cl	37	4·625
chlorate *M.**		$ma+o+cl+h$		57	7·125
ns with nic acid,		$c+2\,o$	$\ddot{C}$	22	2.75
nate of		$ma+o+c+2\,o$		42	5·25
ıs with ıric acid,		$s+3\,o$	$\dddot{S}$	40	5
ate of †		$ma+o+s+3\,o$	$2\,Mg\,2\dddot{S}$	60	5·5
ns with ıoric		$p+\frac{5}{2}\,o$	$2\,\overset{\cdot\cdot}{\dddot{P}}$	35·71	4·46
hate of		$ma+o+p+\frac{5}{2}\,o$		55·71	6.96
ıs with c acid,		$n+5\,o$	$\overset{\cdot\cdot}{\dddot{2N}}$	54	6·75
te of M.		$ma+o+n+5\,o$		74	9·25
s with ic acid,		$ar+\frac{5}{2}\,o$		58	7.25
iate of		$ma+o+ar+\frac{5}{2}\,o$		78	9·75
s with nic acid,		$cr+\frac{5}{2}\,o$		52	6·5
ıate of		$ma+o+cr+\frac{5}{2}\,o$		72	9
ıs with ic acid,				24	3
e of M.				44	5·5

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*rmerly, *Muriate of Magnesia*. † Popularly, Epsom Salts.

NAME.	SYMBOLS.			PROPORTIO
	Dalt.	Whewell.	Berzelius.	Oxygen 8.
Forms with Acetic acid,				50
Acetate of M.				70
Forms with Tartaric acid,				66
Tartrate of M.				86
Bitartrate of M.				152
Forms with Oxalic acid,				36
Oxalate of M.				56
Binoxalate of M.				92
ALUMINA.		$al+o$	2 Al	18
Forms with Water,		$h+o$	2 H	9
Hydrate of A.		$al+o+h+o$	2 Al 2 H	27
Forms with Hydrochloric acid,		$cl+h$	2 H Cl	37
*Hydrochlorate of A.**		$al+o+cl+h$		55
Forms with Sulphuric acid,		$s+3\ o$	$\dddot{S}$	40
Sulphate of A.		$al+o+s+3\ o$		58
Trisulphate of A.		$al+o+3\ s+3\ o$		138
Forms with Phosphoric acid,		$p+\frac{5}{2}\ o$	$2\ \overset{\cdot\cdot}{\overset{\cdot\cdot\cdot}{P}}$	35.71
Phosphate of A.		$al+o+p+\frac{5}{2}\ o$		53·7
Forms with Nitric acid,		$n+5\ o$	$2\ \overset{\cdot\cdot}{\overset{\cdot\cdot\cdot}{N}}$	54

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* Formerly, Muriate of Alumina.

	SYMBOLS.			PROPORTIONAL WGT.	
	Dalt.	Whewell.	Berzelius.	Oxygen 8.	Oxygen 1.
e of					
ate of					
with					
acid,		$ar+\frac{5}{2}o$		58	7·25
'e of					
		$al+o+ar+\frac{5}{2}o$		76	9·5
with					
acid,		$cr+\frac{5}{2}o$		52	6·5
'e of					
		$al+o+cr+\frac{5}{2}o$		70	8·75
with				50	6·25
acid,					
of A.				68	8·5
with					
acid,				66	8·25
of A.				84	10·5
with					
acid,				36	4·5
of A.				54	6·75

utility of a table of this kind will be better under-
from an example or two of its application in practice.
pose," says Dr. Thomson, in his elaborate and pro-
work, entitled First Principles, " I obtain in any
ment 150 grains of dry sulphate of baryta, and that
to know how many grains of sulphuric acid they
, I must look for sulphate of baryta. Its propor-
weight is 14.75, containing five of sulphuric acid. I
erefore,

'5 : 5 : : 150 : 50·847 = sulphuric acid in 150 grains of
'e of baryta.

“For sulphate of baryta, which is a calculation of perpe tual recurrence in the laboratory, a good method is, to hav a part of the process ready finished, and lying at hand fo use. This may be done in the following way :—

The logarithm of 5 is . .	0.6989700
Subtract the log. of 14.75 .	1.1687920
Remains .	1.5301780

“This constant logarithm is to be added to the log rithm of the sulphate of baryta of which you wish to kno the sulphuric acid. In the present example the quantit is 150 grains.

Logarithm of 150 . . .	2.1760913
Add	1.5301780
Sum .	1.7062693

“Now this is the logarithm of 50.847, the quanti found above.

21.5 : 7.5 : : 240 : 83.72 = the weight of common s required.”

Again : “Suppose I have a solution of 90 grains oxalic acid crystals, and that I wish to know how mu bicarbonate of potass will be necessary just to saturate t acid. I find that the proportionate weight of oxalic a crystals is 9 ; consequently 90 is equivalent to ten prop tionals, I find that the atom of bicarbonate of potash 12.625. Consequently, 120.25, or ten atoms, is the qua tity that would be required, if the bicarbonate contain only one atom of water ; but, as it usually contains one a a half atoms of water, 131.875 grains will be requisite.”

The formulæ which I have given from Professor Wh well, and which have not, that I am aware of, been befo introduced into any elementary work, will tend also assist in such calculations, as well as to show by inspe ion the constituents of many compounds.

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